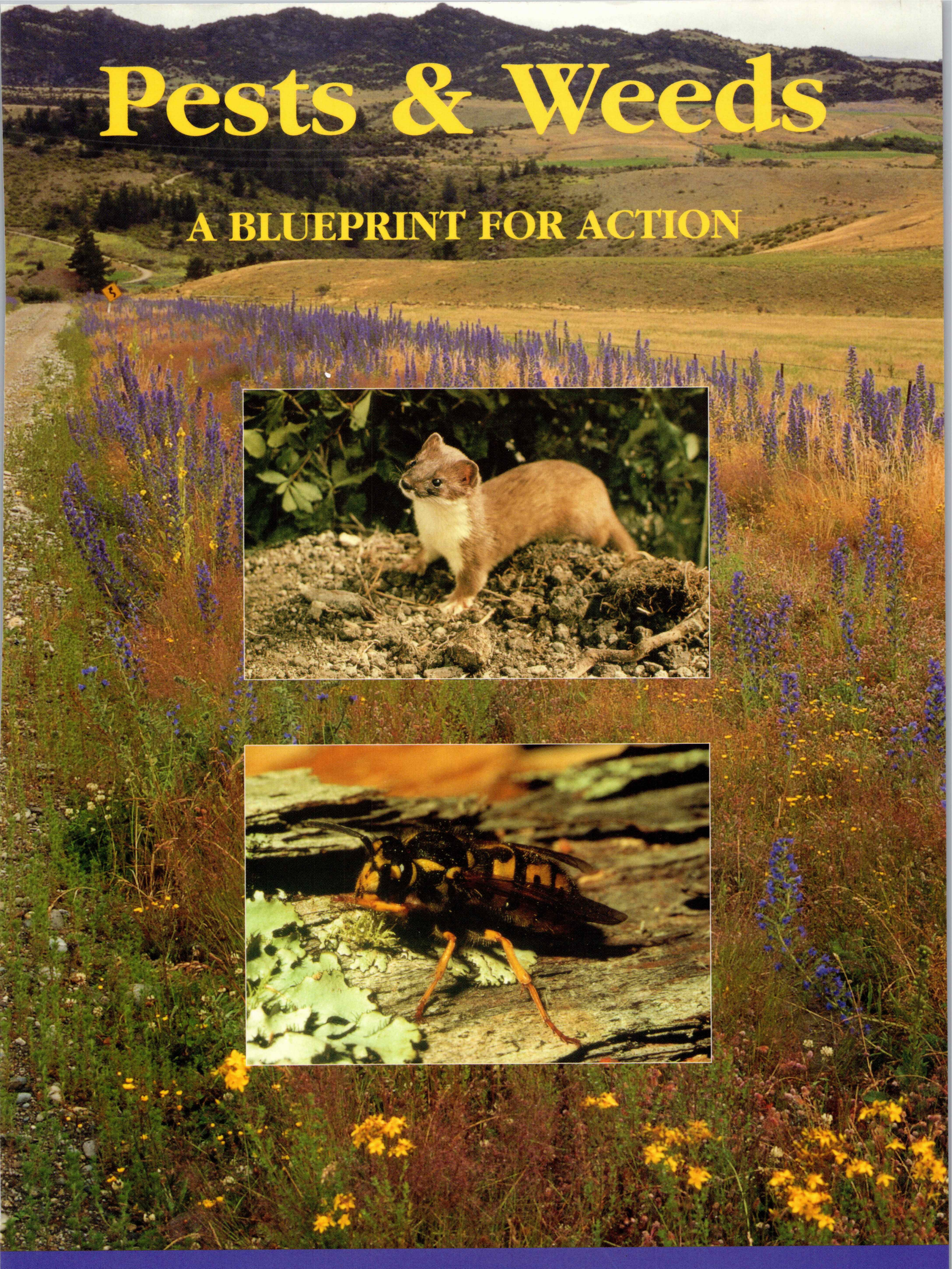
Pests & Weeds

A BLUEPRINT FOR ACTION



NEW ZEALAND CONSERVATION AUTHORITY

PESTS AND WEEDS: A BLUEPRINT FOR ACTION

The cost of pests and weeds to New Zealand is more than $840 million a year — around one percent of gross domestic product — according to this report commissioned by the New Zealand Conservation Authority.

The report outlines the dangers that pests, weeds and pathogens now pose, and provides a blueprint for action to save our sensitive environment and vulnerable industries.

First, there is a concise summary of how introduced organisms impact heavily on our farming, forestry and public health, while also threatening the native animals, plants and wild places which lie at the heart of our unique country. Second, there is an economic review, which provides for the first time an estimate of the economic costs of pest species to New Zealand, and a financial basis for policy review.

Written in popular terms, this book brings together basic facts about the historical invasion of foreign organisms, and their alarming proliferation in recent years. It also shows how New Zealand could stop many of these invasions, and repair the damage already wrought, to its economic benefit.

A 'blueprint for action', it challenges authorities and industries to help save our environment, and our quality of life, by confronting the problems of introduced organisms.

These pages also contain many practical suggestions for controlling the introduced pests, weeds and pathogens which threaten our economy.

NEW ZEALAND CONSERVATION AUTHORITY

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PESTS & WEEDS

The cost of restoring an indigenous dawn chorus

by Kevin Hackwell and Geoff Bertram

A blueprint for action against
the impacts of introduced pest organisms
on the New Zealand environment

NEW ZEALAND CONSERVATION AUTHORITY

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This report has been prepared to inform the public of the costs of pests, weeds and pathogens to New Zealand, and to outline a blueprint for action to halt the damage. Permission to quote from this document, for those purposes, is freely granted. Address further enquiries to the Manager, New Zealand Conservation Authority, PO Box 10-420, Wellington.

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Executive summary

The ecological, cultural and economic impacts of introduced pest organisms are immense and ongoing. Our study estimates that the New Zealand economy loses around $440 million a year due to existing levels of animal pests, weeds and pathogens. To prevent an increase in the level of infestation, private and public sectors spend around another $400 million each year on pest control. The sum of these two figures, $840 million, plus intangibles such as the cost of pest damage to the conservation estate, is close to 1% of Gross Domestic Product (GDP). This figure represents the first approximation of the impact of pests on the New Zealand economy.

In present-value terms (at discount rates of between 5% and 10%), the ongoing annual economic cost of 1% of GDP is equivalent to between $9 billion and $19 billion capitalised burden. This, in theory, represents the value to New Zealand of a guaranteed permanent eradication programme which left no ongoing expenditure need for further control or prevention.

Time is on the side of every potential pest organism which enters the country. Sooner or later many will end up in the wild where they may eventually wreak havoc on our economy, the environment, our cultural values, or our health. Prevention is far more effective than cure. Preventing further introductions is extremely cost-efficient in terms of savings of direct costs to the country and to the environment. Where it is cost-efficient to eradicate existing and potential pest organisms, this should be done as soon as possible. If dealt with early, eradication will be less costly and therefore will be more likely to outweigh the real and opportunity costs of ongoing management. From time to time technological developments can make eradication possible, as has happened with rats on offshore islands.

Eradication of introduced pest organisms and, where this is not cost-effective, their control, is a long-term investment in conservation and primary production. Previous border control systems have had an unbalanced emphasis: they dealt with potential pest organisms which threatened export markets or primary production, rather than with threats to New Zealand's natural environment and its unique flora and fauna.

New Zealand's isolation has not only produced a unique flora and fauna, it has also helped us economically. We have taken advantage of the fact that our isolation has helped to prevent the establishment of many diseases and pests which interfere with primary production in other parts of the world. Without this advantage our present-day economic position would be very different. Much of our tourism industry also revolves around our clean, green image and our relatively unmodified natural environment.

The economic advantages of free trade could be quickly wiped out by new pests of primary production and the natural environment; this could threaten our present competitive advantage. In an increasingly deregulated international trading environment, with greater trade movements between more countries, threats to our biosecurity are increasing. Greater volumes of trade are being brought here at greater speeds and from a wider range of source countries. We are also experiencing greater volumes of international tourism. Strong and comprehensive border control is essential.

The Government must resist pressure to reduce the effectiveness of border control policies and practices. To take full advantage of the biosecurity mechanisms in international trade agreements, we must ensure that we maintain and strengthen the scientific and technical support base of our biosecurity infrastructure.

Most of the biosecurity threats to our economy also threaten New Zealand's natural environment and our unique cultural heritage. Introduced pests threaten all our natural ecosystems to some degree — in some instances this threat is very significant. Many of our native species have been driven to extinction or to the brink of extinction by the impacts of introduced pests. The impact on customary resources and values of tangata whenua has been dramatic. Many native plants and animals, once important resources of food or materials, are now so threatened by introduced pests that they are unavailable for Maori use.

Some of our native species have become devastating pests in other parts of the world. New Zealand should insist that biosecurity standards for the export of organisms and produce are as high as those required for the importation of organisms and produce.

Even if we were able to stop all new introductions of pest organisms immediately, the annual cost of pest control could well continue to rise in the foreseeable future: some pest organisms already established in the country have not yet become invasive in the wild, or are in the invasive stage but have not yet been identified as such.

Recent experience suggests a failure to learn from repeated past mistakes. Short-term commercial pressure for introductions of potential pest organisms has been allowed to override the potentially enormous, and long-term, negative economic and ecological consequences of those introductions. Any proposed introduction should be subject to a detailed and vigorous analysis of its potential to become a pest.

Quite recently, tussock moth, clover root weevil, fruit fly and the southern saltmarsh mosquito pests have successfully evaded border control before they were detected. If border control had been successful, millions of dollars spent on the eradication programmes and considerable inconvenience for many affected by the control programmes could have been avoided.

The present focus on inspections and remedial action at our ports of entry should be strengthened. At the same time, greater emphasis should be placed on surveillance for introductions via uncontrolled routes of entry and on well-policed biosecurity management — such as cleaning and fumigating at the ports of origin. Containerised trade is rapidly increasing. Given that the majority of containers are not inspected at our borders and potentially contaminated containers may be transported great distances within the country before being opened, we must ensure a greater level of biosecurity awareness of all those involved with such trade.

The Biosecurity Act and the recent implementation of the Hazardous Substances and New Organisms (HSNO) legislation, administered by the Environmental Risk Management Agency (ERMA), provide the opportunity to strengthen the wide input into biosecurity operations. Such input may come from statutory agencies such as the Department of Conservation, tangata whenua, environmental organisations and other interested groups and individuals.

The structures for dealing with intentional introductions are clearly established. Recent experience indicates nevertheless a lack of clarity as to who is responsible for co-ordinating the response to unintentional introductions. There are also grounds for concern about the inadequacy of co-ordination of research into biosecurity issues.

The commitment of the effort should be, wherever possible, to the eventual eradication of the pest organisms in the wild. This requires a commitment of effort of both long-term resources for research into pest eradication methods, as well as the short- and medium-term resourcing of efficient pest control and management.

The recently released draft New Zealand Biodiversity Strategy 'Our Chance to Turn the Tide' sets its sights too low by recommending goals which will do little more than just hold the line over the next 20 years, allowing local extinctions of native species to continue. Implementing its goals will cost an extra $46 million a year for a range of initiatives, of which biosecurity and pest management are only a part. Such a sum is clearly insufficient.

Poor biosecurity in the past has led to a pest problem which is a massive drain on the present economy (around 1% of GDP). An ambitious biodiversity strategy with a vigorous biosecurity regime, dealing with existing and potential pest *species, is clearly necessary. This would not only assist the recovery of many threatened native species and degraded natural ecosystems, but would also be of significant benefit to our economy.*

RECOMMENDATIONS

1. Levels of funding

Pests are costing the country around 1% of GDP per year. We need to improve our levels, and effectiveness, of border control. We also need to increase research into, and operational capacity to carry out, pest organism detection, eradication and control. These have the potential to return financial and other benefits many times the value of the initial investment.

The New Zealand Conservation Authority (NZCA) recommends:

1.1 That the present public investment in our biosecurity — border control, surveillance, pest eradication and control — be increased from around $200 million a year to $250 million a year, as a first step towards increasing investment in pest control to $400 million annually by the 2004/05 financial year.

1.2 That funding for research into new methods of control and eradication should be significantly increased.

1.3 That provision be made within Vote Biosecurity for:

- the costs of pest surveillance and routine monitoring;
- a significant contingency fund which can be called upon by central and regional agencies when dealing with outbreaks of new pests.

1.4 That extra funding be allocated to give effect to the recommendations made in this report, such as 1.2, 1.3, 2.1, 3.2, 4.1, 4.2, 4.3, 4.4, 4.8, 5.1, 5.2, 5.3, 6.2.

2. Better co-ordination of pest organism control and research

ERMA and the HSNO legislation are primarily focused on managing the process by which intentional new organism introductions are made. The Biosecurity Act spreads responsibilities for protecting New Zealand against unintentionally introduced pest species over many different central and regional government agencies, and even industry groups. The Biosecurity Act provides a framework for it to be addressed, and the Biosecurity Council of officials goes some way towards addressing the response of government agencies. Yet, we lack a single body with the resources and full-time statutory responsibility to prepare and co-ordinate the response to unintentional introductions, and to co-ordinate our many other biosecurity needs.

The NZCA recommends:

2.1 That the Government develop more effective mechanisms to ensure the effective co-ordination of the country's many biosecurity needs. The new mechanisms should ensure:

- the preparation of incursion contingency plans for identified potential pest species;
- overseeing of comprehensive monitoring regimes, not only at points of entry;
- access to high-quality scientific and technical resources, particularly taxonomic expertise, to guarantee accurate pest species identification;
- ready access (possibly on a retainer basis) to the wide range of scientific, cultural, technical and practical knowledge needed to promptly and efficiently deal with new incursions;
- resources (including trained staff) to be available for deployment at short notice anywhere in the country, so a wide range of possible new pest organism establishments can be dealt with — both when a new pest organism enters the country and where a pest organism enters a new region of the country;
- co-ordination of inter-agency research into pest organism control and eradication;
- development of a National Policy Statement to provide guidance on the implementation of the biosecurity provisions of the Resource Management Act.

This could be achieved by:

- establishing a new dedicated government department;
- contracting this function out to a non-government agency; or
- allocating these responsibilities to an existing government agency.

Any chosen mechanism would have responsibility to recognise and protect tangata whenua values and priorities.

3. 'Safe trade' versus 'free trade'

It is essential that New Zealand should fully exercise its right to 'safe trade', under international agreements such as GATT. These agreements require that biosecurity barriers to trade must be based on sound science, be transparent, technically justified, and sufficient only to protect plant and animal health. It is therefore essential that we increase our scientific and technical expertise in the fields of biodiversity and biosecurity for indigenous and primary production.

The NZCA recommends:

3.1 That the Government negotiate for the inclusion of a precautionary principle into the biosecurity provisions of all international trade agreements.

3.2 That there needs to be a significant investment increase in the scientific and technical support available to our biosecurity services, particularly taxonomic and risk assessment support.

4. Greater resourcing of Biosecurity/Border Controls

It is far safer to prevent potential pest species from hitching a ride to New Zealand than to have to deal with them when they arrive here. Hence, greater emphasis should be placed on well-resourced policing of biosecurity requirements at countries of origin. While risk assessment is a valuable tool to aid the prioritisation of limited resources for border control work, we must be careful not to become over-reliant on it. Potential pests, and the people associated with their transport to New Zealand, may not 'behave' in practice as they are meant to in theory.

The NZCA recommends:

4.1 That New Zealand biosecurity staff be stationed overseas. The close coincidence of biosecurity and border control requirements of Australia and New Zealand may allow for sharing the costs and personnel required to carry out this function.

4.2 That increased resources should be provided to MAF Quarantine for the detection and elimination of potential pests of the natural environment. This should be in addition to, and distinct from potential pests of primary production which presently receive the most attention. Training and back-up technical expertise for border control officers should be included.

4.3 That a greater diversity of effective border control information be available in a variety of languages to both passengers and crews of all in-bound planes and ships, including cargo carriers. The effectiveness of this information should be regularly monitored.

4.4 That extra resources be allocated for the protection of marine ecosystems which are vulnerable to infestation from alien pests.

4.5 That successful applicants who import a new organism be required to post a bond, or take out insurance, to cover the costs of eradication should the organism establish in the wild.

4.6 That corporates responsible for bringing contaminated goods into the country be prosecuted. They should be dealt with in the same way as individuals bringing undeclared fruit and other risky goods into the country.

4.7 That the legislation be immediately strengthened, if the powers of the new HSNO, Biosecurity Acts and other relevant Acts prove inadequate to prosecute for breaches of biosecurity.

4.8 That border control services be subject to regular independent audit.

5. Control of pests which threaten conservation values

To succeed at restoring a dawn chorus we will have to halt, and in some areas reverse, the loss of indigenous biodiversity. This requires that the organisations with primary responsibility for protecting that indigenous biodiversity — the Department of Conservation and the Regional Councils — become more effective at controlling and, wherever possible, eradicating pests of the natural environment. The allocation of resources should follow the principle of giving priority to protecting the least modified habitats and those native species under greatest threat.

The NZCA recommends:

5.1 That national eradication programmes be implemented and owners compensated from a national biosecurity contingency fund, where species which have already been introduced legally prove to be potential pests (such as *Phragmites*, chinchilla and Bengal tiger cats).

5.2 That Regional Councils and the Department of Conservation:

- expand the number of partnerships with Iwi to protect taonga species from the effects of introduced pests;
- enhance their capability to provide scientific and technical input into assessing border control/biosecurity risks for indigenous biodiversity;
- take a strong stance in their advocacy for the maintenance of indigenous biodiversity on private land in partnership with private landowners;
- encourage primary industries which benefit from introduced species that are also environmental pests, to enter into accords in which they take responsibility for limiting opportunities for establishment of wild populations and for dealing with wild populations which do establish;
- ensure that the few rivers, lakes and wetlands which are free of exotic fish species are regularly monitored, and contingency plans are drawn up in consultation with tangata whenua, local conservation organisations and Fish and Game Councils, for dealing rapidly with any introductions which are detected;
- ensure the protection of indigenous fresh water biodiversity and act effectively to prevent further spread of exotic species. Wherever possible, introduced fresh water species should be eradicated where they appear beyond their existing distribution;
- work to establish the freshwater equivalents of 'mainland islands' where indigenous freshwater species are restored and introduced species removed. Such initiatives would have to be developed with close participation of tangata whenua, Fish and Game Councils and other interest groups;
- implement measures to protect the marine and coastal ecosystems from infestation from introduced pest species, particularly from ballast water discharges and fouled ship's hulls.

5.3 That the Department of Conservation:

- strongly advocate for a national biodiversity strategy which does much more than just hold the line on the present rate of extinctions;
- ensure that the conservation principles of the Conservation Act and the National Parks Act take priority over other demands on the conservation estate, where those demands threaten indigenous biodiversity. For example, indigenous biodiversity is being threatened by wild animals which also have recreational hunting values. It is technically and economically feasible to eradicate thar, wallaby, chamois and some populations of deer to protect indigenous biodiversity, and this should be done;
- expand its pest control of forest browsers such as deer, goats and possums, and of predators such as mustelids, rodents and feral cats;
- ensure that there are comprehensive quarantine programmes for all the offshore islands which have had successful mammal eradication programmes;
- establish priorities for control and prevention of spread of weed species for each region.

6. International responsibilities

New Zealand has been the country of origin for the export around the world of pest species such as possums, wallabies and hedgehogs. Evidence has also come to light recently that wildlife diseases are being introduced into the Antarctic environment as a result of poor quarantine control.

The NZCA recommends:

6.1 That the government implement its international biosecurity obligations by legislating to ensure that known pest species cannot be exported, except to their country of origin.

6.2 That New Zealand advocate for strict international quarantine to protect Antarctic wildlife. As a first step it should police such a quarantine regime for all goods and personnel travelling to Antarctica from New Zealand.

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against the impacts of
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By Kevin Hackwell

Restoring an indigenous dawn chorus

The Department of Conservation (DOC) recently published a Strategic Business Plan for the period 1998 to 2002, entitled 'Restoring the Dawn Chorus'. The title of this plan conveys a very important sentiment: the abundance and diversity of indigenous birds is a very good indicator of the health of the natural environment. Throughout the country, the native dawn chorus greeting the morning sun is falling silent. Habitat modification, competition, predation from introduced pest species and introduced diseases continue to exact a terrible toll on our native birds and other native fauna.

What will it take to restore an indigenous dawn chorus? The natural environment first needs to be protected from further degradation; then we need to work to restore much of what has been lost. Central to this process will be the goal of controlling, and wherever possible, the eradication of the major introduced pest organisms: introduced weeds, animal competitors, predators and diseases. The barriers to achieving such a vision are considerable, but not insurmountable. Recent advances in New Zealand give hope that we can continue to lead the world in this field.

Restoring our dawn chorus will not only signal a significant improvement in the health of our natural environment, it will also have large beneficial effects on our economy. The measures needed to deal with introduced pest organisms which threaten conservation and cultural values will also have a huge impact on the pests of our primary industries. The economic costs of introduced pest organisms are a significant drag on the country's productivity and its ability to compete successfully in the global economy. It makes both economic and environmental sense to invest in long-term strategies to deal with these problems.

This important task will require an investment of significantly greater resources than are now being provided for the job. The New Zealand Conservation Authority has produced this paper to provide an overview of the size of the problem, in both environmental and economic terms, and to indicate the size of the investment that is required to address the problem.

The vision of a restored indigenous dawn chorus is one of hope for a sustainable future, where our natural heritage is celebrated, treasured and protected.

New Zealand's natural heritage: different in almost every respect

In the natural world there are two particular characteristics which help to make New Zealand stand out.

The first distinction is that no other land mass of New Zealand's size has been isolated from the 'rest of the world' for such a long time.The land mass which was eventually to become New Zealand separated from the southern super-continent, Gondwana, some 80 million years ago.This was during the time of the dinosaurs and before the evolution of mammals.

In 80 million years of separation, New Zealand has developed a set of plants and animals that are truly very different from those elsewhere. In all but the last fraction of that period, the only land mammals able to reach New Zealand were the ancestors of our three species of bat.

In the absence of mammals, the ecological niches taken up by other mammals in the rest of the world have been filled in New Zealand by a very different range of animals.The roles of the smaller rodents were taken up by giant snails, giant insects and flightless birds.Those of grazers such as rabbits, pigs, goats, cattle and deer were taken up by birds: some, but not all, flightless.The most famous of these were the moas (see box:World Records).

The second distinction is that New Zealand was the last large, habitable land mass to be colonised by humans. Polynesians arrived some 800 to 1000 years ago to a country which was almost completely forested below the snow line — save for the wetlands, the wide, braided channels of the eastern South Island rivers, and a few areas in the central North Island and central Otago.

At no time in the last 65 million years had New Zealand experienced such massive and rapid ecological changes as following the arrival of Polynesians, and of Europeans just a few centuries later. Both peoples have been responsible for huge levels of habitat modification.Within a few hundred years of arrival, the early Maori had used fire to clear a third of the country's forest cover from the drier east coast.Within a period of just one hundred years from their arrival, the Europeans — creating an England of the south seas — burnt and logged another third of the forest cover from the wetter western coasts of both main islands and from much of the inland North Island.

This habitat modification led to many plant and animal extinctions.However, it is likely that many species disappeared before their habitat was lost: they were victims of hunting and of the introduced pest species which both Maori and Europeans brought with them.

Along with yam, taro, gourd and kumara, the first Polynesians brought dogs and rats.Both the kuri (Polynesian dog) and the kiore (Polynesian rat) played a significant role in the extinction of many of the ground-dwelling animals. Lizards and

World records

Because of New Zealand's long isolation, its flora and fauna hold many 'world records' — far out of proportion to its relatively small number of species.

The world's largest insect, the giant weta, weighs as much as a blackbird. The largest bird, the giant moa, weighed in at over 400 kg and was up to 3 metres tall. The smallest flightless bird, the bush wren, weighs only a few grams and is only 8 cm high. The largest known bird of prey, the Harpagornis eagle, had a wingspan of over 4 metres and talons larger than those of the Bengal tiger. The kakapo is the world's largest parrot and the only flightless and nocturnal parrot. The world's only alpine parrot, the kea, also holds the world record for the bird with the longest juvenile (learning) phase for its young.

Our several frog species are the world's only frogs which give birth to live young; other native frogs do not have a free-swimming tadpole stage. Only in New Zealand are there lizards that do not lay eggs but give birth to live young instead. The tuatara is the closest living relative of the dinosaurs.

tuataras, frogs, insects and birds, including huge seasonal mainland populations of breeding seabirds would have fallen victims of the massive plague of rats [1]. Within just a few decades of Polynesian arrival, many animals previously found throughout the country are likely to have been eliminated from the mainland and would have survived only as smaller, more vulnerable, populations on offshore islands.

Many of the most vulnerable species were driven to extinction during this phase. So when Europeans arrived several hundred years later, with a much greater number and range of pest plants and animals, there were actually fewer extinctions. The earliest Europeans to find New Zealand began the process of further introductions. Captain Cook deliberately released goats and pigs on early voyages and almost certainly also unintentionally introduced new predators: the black rat and cats (see box: Predators). The new colonisers were quick to deliberately introduce thousands of new species of plants and animals, building an agriculture industry based on millions of sheep and cattle. The rapid growth of international trade also provided the opportunity for huge numbers of unintentional introductions to occur.

Predators aplenty before humans

It is a common misconception that in the absence of mammals, New Zealand had no predators. This was not the case. Over millions of years, the animals of the forest and open country all would have feared a sudden death from stealthy predators. There were seven different birds of prey, including owls, falcon, nightjars, giant weka, and hawks.

We may not have had a huge predator such as a lion, but a massive eagle, the Harpagornis eagle, sat at the top of the food chain. It was, until its extinction just a few hundred years ago, the world's largest flying bird. It could fell a 400 kg moa with its massive talons, which were larger than those of the Bengal tiger (the world's biggest surviving predator).

There are key differences between the way in which bird predators operate compared to mammalian predators. Birds of prey rely predominantly on their highly developed sense of vision. Their prey evolved defence strategies to deal with this, such as camouflage; the ability to 'freeze'; staying within the forest where it is difficult for large birds of prey to fly; and being active at night rather than during the day.

Such strategies were inadequate to deal with mammalian predators which combined good visual skills with well-developed senses of hearing and smell, and which are often active at night.

Impact of pest organisms on conservation values

Invasive pests and weeds have become the greatest single threat to biodiversity on land, surpassing even habitat loss[2].

Introduced mammals that have become established in the wild include the possum, six species of deer, five species of wallaby, Himalayan thar, chamois, the hare, the rabbit, three species of mustelid (stoat, weasel, ferret), four species of rodent (Norway and ship rats, kiore, and house mouse), the hedgehog and feral populations of domestic animals including goats, cattle, horses, sheep, pigs, dogs, and cats (Table 1).

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[1] Holdaway (1989)

[2] Department of Conservation & Ministry for the Environment (1998)

Table 1. Estimated number of exotic species established in the wild in New Zealand [3,4,5,6]

	Established exotic species	*Native species*
Vascular plants	2000	2450
Terrestrial mammals	32	3
Freshwater fish	30	27
Terrestrial & freshwater birds	36	155
Seaweeds	20	700+[7]

There is recent evidence that a fifth species of rodent, chinchilla, should now be added to this list[8]. Unfortunately, it may not be too long before other recent commercial introductions such as alpaca or the Asian tiger cat/domestic cat hybrid join as well.

Much of the work to protect endangered wildlife is oriented towards controlling the effects of introduced predators and competitors such as protecting kokako populations from both predation (of eggs) and competition from possums. At least 94% of young North Island brown kiwi are failing to reach adulthood, largely because of predation. In Tongariro Forest, intensive mustelid trapping has had only very limited success because as soon as the predators are removed from around the kiwi populations, new animals move in from the surrounding, un-trapped areas. Young kiwi are being taken from some areas and captive-raised until they are large enough to defend themselves from predation. This cannot go on forever and it highlights the need for research into new techniques for mustelid control.

It is not just bird populations that are under threat from predation. Many of our unique giant snails, giant insects, native frogs and lizards have already been driven to the edge of extinction from predation by pigs and mice, rats, mustelids and possums. In some parts of the country, grazing and browsing by new mammalian pests threatens native plant species, such as mistletoes.

Weeds also threaten many native communities. Several plant species of now-recognised weeds entered New Zealand as commercial ornamental plants (old man's beard, ginger), plants for pasture improvement (couch, gorse, *Paspalum*, *Spartina*) or plants for commercial forestry (*Pinus contorta*, *P. radiata*). Of the over 2,000 introduced plant species which have become established in the wild, some 240 species are currently recognised as having significant impacts as weeds of natural communities. Since the 1860s, on average two new signifi-

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3 King (1984)
4 McDowall (1990)
5 Vitousek, et al. (1997, p.4)
6 Nelson (1998)
7 Adams (1994) puts the number of recorded seaweed species at around 700. The actual figure is likely to be several hundred higher than this.
8 Johnson (1996)

cant ecological plant pest species have established in the wild each year[9]. Unfortunately this trend shows no sign of slowing down.

Many endangered plant species are either under pressure from introduced grazing and browsing animals, or are threatened by habitat modification due to invasive weeds such as old man's beard, lupin and Buddleia. The invasive spread of many plant pests is assisted by disturbance caused by humans or animals. Domestic animals can, when not effectively managed, cause significant damage to stream banks, can spread seeds and open up forest understoreys.

While quite a lot is known about the impact of mammal and bird pests of relatively unmodified terrestrial ecosystems, less is known about the impacts of terrestial plant pests or of insect pests in indigenous ecosystems. The situation is even worse for the impact pests can have on freshwater and marine ecosystems.

Freshwater fisheries

The majority of the exotic fish fauna was introduced between 1870 and 1910. At that time the indigenous freshwater fish fauna was poorly known. Even so, at the time that trout were being introduced, objections were voiced by some Maori and European commentators concerned about their effect on indigenous fish. Nevertheless, trout were introduced; several large native fisheries were quickly destroyed and, with them, the economic and cultural base of several iwi[10].

The lake-living native fish were once taken by Maori in very large quantities from Lakes Taupo, Rotorua, Rotoiti and others, including South Island lakes. Such fish formed a principal food for the Arawa. Ngati Pikiao netted them in the Ohau Channel, sun-dried and stored them for winter use or for profitable barter with West Coast iwi.

Koaro were once so abundant in Lake Taupo that after heavy winds they were cast up on the beaches in large numbers, and gathered and used for food. They were taken from the lake itself using huge seine nets, and were also caught as they migrated from the lake and up tributary streams. As trout became numerous, koaro became scarce and the social, cultural and economic structures which Maori had built around the koaro fishery were destroyed.

Following the decline in koaro numbers, common smelt were liberated in Lakes Rotorua and Rotoiti in 1917 and later into other lakes such as Taupo in the mid to late 1920s. For the Ngati Tuwharetoa of the Taupo area, the loss of the koaro fishery has been partly compensated by the control of the trout fishery which replaced it. This has not been done elsewhere and many iwi still feel strongly about the severe reduction in taonga freshwater species.

Koaro was not the only native freshwater species to have been impacted by trout introduction. Freshwater crayfish

[9] Department of Conservation (1997a)

[10] McDowall (1990)

(koura) and crab, dwarf inanga, giant kokopu and brown mudfish have also suffered considerably. Acclimatisation societies ran drives to reduce eel numbers, fearing (with little evidence) that eels were taking significant numbers of young trout.

Trout have also impacted on crested grebe populations because of the reductions in koaro populations on which the grebe fed. It has been suggested that the decline in blue duck may also be in part due to competition with trout which have similar tastes in food and living places.

Unfortunately, introductions of exotic fish have continued, with the spread of catfish in the lower Waikato being blamed for the decline of the eel populations. Grass carp have also established wild populations and the recent establishment in the lower Waikato of koi carp, with its propensity for severe habitat disruption, is a matter for serious concern.

There are at present some 20 introduced freshwater species established in the wild — a number greater than that of known native species. Waterways and lakes which are free or substantially free of introduced species are now increasingly rare and have considerable value. Koaro have persisted in great abundance in lakes such as Rotopounamu (Tongariro National Park), Marion, Christabel and Chalice where neither rainbow nor brown trout have been released. These lakes have very high value for indigenous fish and it is essential that their legal protection against the introduction of exotic fish is policed[11].

Along with the introduction of exotic fish species, there has been the introduction of aquatic weeds. Currently more than 19 species of introduced plants are major aquatic weeds, including alligator weed, *Hydrilla*, water net, *Lagarisiphon*, *Egeria*, arum lily, *Salvinia* and yellow iris[12]. Many of these were originally brought into the country as ornamental plants for garden ponds or freshwater aquaria. These plants threaten freshwater communities in lakes, ponds and rivers by choking and clogging waterways, depleting the water of oxygen, and destroying native plant communities. Some such weeds have an economic effect on hydro-electric power generation. Unfortunately, introduced aquatic weeds dominate the native plant communities in most lakes or lowland rivers.

Marine ecosystems

Already in New Zealand there are several examples of marine pests being introduced through ballast water and as bio-fouling on commercial and leisure vessels. Huge volumes of ballast water are brought to New Zealand every year, notably in bulk wood-chip carriers, and boats which export aluminium. This threat could be particularly dangerous in the pristine waters of Fiordland if proposals for the export of fresh water in bulk carriers were ever to be put into effect.

One of these pests is *Undaria pinnatifida*: a large and eco-

[11] McDowall (1990)

[12] Department of Conservation (1997)

logically aggressive species of Asian kelp. A native of Japan, Korea and China, it is now present in Australia, New Zealand, France and Britain; their introductions have been recognised over the past 25 years. New Zealand has now possibly three varieties of *U. pinnatifida,* suggesting multiple introduction events.

Since its discovery in Wellington Harbour in 1987, this species has spread rapidly around the country. Although the initial records were from modified habitats, *Undaria* is now colonising areas of open coast. Most recently it has been discovered on marine farming (salmon and mussel) equipment in Big Glory Bay, Stewart Island, that had been transported from the Marlborough Sounds.

The eradication of *Undaria* at Stewart Island is under way. As the population is restricted to marine farming equipment and two sites on the shore, there is a good possibility of removing the founding material before it spreads out of Big Glory Bay into natural habitats elsewhere in Paterson Inlet. The eradication work is being conducted by DOC with funds from Vote Biosecurity, and is regularly reviewed by an inter-agency group involving DOC, NIWA, Cawthron Institute, Te Papa and the University of Otago[13].

It's the putting right that counts

In the face of such unrelenting pressures, and general lack of resources to deal with them, one could be despondent and resigned to ultimate defeat. But this has not been the New Zealand attitude.

Faced with the consequences of habitat destruction and the impact of the exotic animals and plants which they had brought here, both Maori and European cultures have worked to turn the tide. New environmental knowledge (matauranga Maori) has been applied and practices and customs (tikanga) are altered to conserve what remains.

Taonga species and materials are fundamental to Maori culture and identity. There is a strong commitment to the conservation and restoration of native animals, plants and habitats so that future generations will be able to enjoy this heritage.

This commitment includes dealing with the impacts of pest species. Recent successes against several well-established and significant introduced pests point the way to a brighter future for conservation.

The Kapiti experience

The rugged, 1968-hectare Kapiti Island is one of New Zealand's oldest nature reserves on an offshore island and is home to many rare bird species, including the last-viable population of the little spotted kiwi. The majority of the island is a Nature Reserve, with the remaining area in Maori ownership.

Possums were introduced to Kapiti in 1893 and their numbers increased rapidly to threaten the island's vegetation and wildlife. Following several years of studying the ecology of possums on the island, a programme involving intensive trapping, aerial poisoning and trained dogs was begun in 1980. The prevailing wisdom of those involved with conservation and the control of wild animal populations was, that it would be extremely difficult to eradicate a wild animal of the possum's size and numbers from such a large and rugged area. But by 1986, with the co-operation of the Maori landowners, some 21,000 possums had been killed and the pest systematically eradicated from the island[14].

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[13] Nelson (1998)

The elimination of rats from islands provided a further challenge: in the mid 1980s this was generally considered impossible. Building on earlier work, a plan was devised to use an intensive network of poison bait stations for rat eradication from an island of moderate size (150 hectares): Breaksea Island, off the coast of Fiordland. This rat-free island would be used as a habitat for endangered lizards, eliminated from other nearby habitats by rats. The experiment was successfully carried out in the early 1980s, and in the following years variations of this and other techniques, including aerial bait drops with new types of poison, were tested on a variety of islands with different rodent species. To date, rats and mice have been successfully eradicated from 50 islands.

Experience on the smaller islands led to aerial distribution of bait in order to eradicate brown rat and kiore from an island the size of Kapiti. After several years of preparation this was achieved in 1997. The island was officially declared rat-free in 1999. Kapiti Island is now free of all introduced mammals, greatly enhancing its value as a nature reserve to which rare and endangered species can be transferred to establish new, viable populations as part of the programme to protect them from extinction. Whenua Hou (Codfish Island) was targeted in 1998, and Little Barrier, Campbell and Raoul Islands are all being considered for future work.

Significantly, removal of rats from Kapiti led to an increased presence of some weeds on the island. This and other similar experiences highlight the lack of knowledge about the ecosystem effects of pests; they reinforce the need to take an integrated approach to the management of pests where the impacts on the whole habitat are considered.

The techniques developed to eradicate possums and rodents on Kapiti have been adapted for intensive control of these and other pest animals in 'mainland island' reserves. These are intensively managed areas of habitat on the mainland where endangered species are protected.

The investment in eradicating introduced mammals from island reserves such as Kapiti, and the large investment in releasing rare and endangered species on these islands, is still threatened by inadequate visitor quarantine provisions.

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[14] Cowan (1992)

Taonga protection and recovery

Conservation interests and tangata whenua share much ground in relation to introduced pest organisms. This stems from the desire to provide protection for taonga species and the priority iwi place on such issues, plus the requirement of the Conservation Act that effect must be given to the principles of the Treaty of Waitangi. There has been much co-operation between tangata whenua and DOC in conservation efforts throughout the country.

For example, Ngati Rangi have been intimately involved in the protection of important forest habitat at Rangataua, on the south-eastern slopes of Mt Ruapehu. These superb forests not only have high numbers of bird species such as kaka, kakariki, robins and kereru, but also a recently-discovered, large colony of short-tailed bats — a species that had been feared extinct on the mainland. In a successful partnership with DOC, Ngati Rangi have been fully involved in the development of management strategies for the area and in the practical efforts to control possum and other predators[15].

For Maori, the coast traditionally provided both food and materials. Several coastal plants with long fibrous blades from rhizomes were valuable for decorative work in wharenui: kiekie, harakeke and toetoe kakaho, but perhaps most prized of all was pingao. Low sand-dunes sprouting golden tufts of pingao used to be a highlight of New Zealand's 52,000 hectares of dune-lands. Their harvest and use was governed by tikanga Maori, which preserved the species and its habitat.

European pastoralism coveted this low-lying dune-land, but most attempts at grazing led to dune erosion. The response to this erosion was to plant marram and lupin, thus encouraging pingao's decline. The aggressive marram crowded out pingao, and better resisted grazing and vehicle damage.

Throughout the country, marae close to the coast are working with DOC on pingao recovery — which involves gathering of local seed, propagation, potting-on and then planting out at suitable sites. Priority at these sites is to prevent the spread of marram and to control pests[16].

The restoration of titi (mutton bird) colonies on the mainland is being jointly carried out by Kai Tahu whanui and Otago University. Restoration of mainland titi colonies provides an important link with the greater Kai Tahu effort in relation to the conservation and seasonal harvesting of mutton birds on the Titi Islands.

Restoration of mainland titi colonies involves protection from predation by feral cats, ferrets, stoats, ship and brown rats, plus habitat enhancement. These actions will also benefit hoiho (yellow-eyed penguin) and korora (little blue penguin) that breed in the vicinity[17].

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15 Department of Conservation (1995)
16 Aimers (1993)
17 Jones et al. (1997)

The wilding tree accord

Species used for commercial production may escape and establish themselves beyond the owner's boundaries (so-called wilding).What level of responsibility should the original owner, or the industry take?

This question was recently addressed in the Otago-Southland regions in response to concerns about the impact of wilding trees on indigenous vegetation, particularly tussock grasslands. Wilding trees have a variety of origins, including commercial forestry, plantings for soil conservation, landscape and shelter purposes.

The Royal Forest and Bird Protection Society and the Institute of Forestry took the joint initiative to eliminate or minimise the impacts of wilding trees.This has resulted in the formation of a working party drawn from the commercial forestry companies, major land holders or land managers, local authorities, Conservation Boards, DOC, iwi, Federated Farmers, Forest and Bird and other conservation groups.These parties have undertaken to address the control and, where feasible, eradication of wilding trees by means of an Accord[18].

Eradication where possible

In the absence of feral mammal populations, our native flora and fauna would undergo an enormous recovery. The changes to Kapiti Island, from the early 1980s to the present day, are profound. The forest regeneration is profuse. The bird populations have increased dramatically — compared to the mainland, the island's dawn chorus of native species is stunning. Recent regeneration on Rangitoto Island, following the eradication of possums and wallabies, offers another graphic example of the benefits of eradication. There are good reasons to try and make mainland New Zealand, or significant parts of it, like this.

DOC's budget uses roughly $60 million for ongoing management to deal with the impacts of pest organisms. It is clear that a programme of investment in research into more efficient pest control systems, and where possible eradication — particularly of the most damaging species — would be very worthwhile (see box: Prerequisites).

With public support, political will and resources, existing technology makes it possible to eradicate feral populations of wallaby, Himalayan thar, chamois, and several deer species with limited distributions, as well as isolated populations of widespread deer species.These are all large animals with well-defined populations and limited distributions.

Around $40 million of public money is spent each year on attempting to control possum numbers for conservation protection and to control the spread of bovine Tb. Possum control occurs in only a portion of the native forests which are being heavily impacted by possum browsing[19]. In the near future, an effective possum control agent, combined with other techniques, may be capable of eradicating this pest.

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[18] Dickinson (1998)

[19] Cowan (1996)

Prerequisites for effective eradication

There are several important prerequisites for an effective eradication programme of a pest species. These are:

1. that all individuals can be detected, even at very low densities;
2. that properly resourced control methods are available for effectively killing all individuals in the population faster than they can be replaced; and
3. that immigration of individuals from outside sources can be prevented or effectively controlled.

Local support for both the eradication objective and the control methods used is also very desirable.

Present techniques for possum eradication are so labour-intensive that it is difficult to scale them up to be effective in very large mainland areas.The goal of possum eradication on the mainland could only be achieved through other, less expensive techniques. Landcare Research scientists are developing techniques to make possums sterile through an auto-immune reaction[20] . This work has the potential to deal a long-term blow to New Zealand possum populations, but has serious implications for biosecurity arrangements between New Zealand and Australia. It may also involve the use of technology with which the general public is not yet totally comfortable.

If the new technologies are effective against possums, it may not be particularly difficult to adapt them for a range of other species such as stoats, ferrets, weasels, hedgehogs, rats, and hares. These species are generally not kept in captivity and it is possible to ensure through border control that they do not re-establish. Already research is underway in Australia into the biological control of mice using immuno-contraception[21] ; similar research is being carried out in the United States on control of white-tailed deer populations in urban areas[22].

It would be more difficult to deal with feral populations of domestic and commercial species, such as rabbits, cats, goats, sheep, cattle, pigs and deer.While elimination of these species from the wild may one day be possible, re-introductions of animals from domestic sources would present an ongoing problem. The existence of commercial and domestic populations would also pose problems of public acceptance of control methods, even if these could be tailored to ensure the safety of domestic animals. Farmed animals could be vaccinated against the organisms which spread the auto-immune sterilisation mechanism in the wild populations. Should vaccinated animals escape into the wild, their non-vaccinated offspring would then be vulnerable to the control agent.

Some pest species are also used extensively for recreational and commercial hunting; there would be considerable resistance from these interest groups against any eradication proposals.

Deer

For many years it had been assumed that the ultimate conservation goal of eradicating large browsing mammals such as wild deer from our native forests was impossible. The only credible option for conservation was to use a variety of techniques such as commercial and recreational hunting or poisoning for controlling animal numbers to some sort of 'acceptable' level which the native habitat might sustain. This thinking has guided a raft of legislation relating to introduced wild animals that have recreational hunting value, despite their severe impacts on the environment.

It has become increasingly clear that control of animal pest

[20] Cowan (1996)
[21] Hinds et al. (1998)
[22] Miller et al. (1998)

numbers often just slows the rate of continued habitat decline. An example is the Kaimanawa Recreational Hunting Area: although hunting pressure there is 7.5 times greater than the national average, deer still appear to be progressively eliminating and preventing the regeneration of palatable species[23]. Fostering the regeneration of these plant species requires greater reductions in deer densities than can be obtained by hunting.

The demands of commercial and recreational hunters are in fundamental conflict with the action required to protect indigenous biodiversity. Reversing biodiversity loss in indigenous forests will entail reducing deer densities below the levels achieved by past and present hunting effort. To date there has been no operational poisoning undertaken for deer anywhere and very little in the way of control hunting — despite the presence of many new isolated populations.

If operational poisoning or other new technology became available, then conservation managers would have the option of potential eradication in the wild. Eradication would not only have enormous positive impacts on the health of the country's conservation estate; it would also benefit our primary industries, which are threatened by disease carried by wild animals and which suffer from damage to pasture and crops.

New threats to our biosecurity

How have we fared recently in stopping the flow of new pests into New Zealand?

Illegal threats

It has been argued that the original blunder of introducing rabbits was corrected with the 'crime' of introducing mustelids[24]. Have we learnt much since? The answer to this question has to be both 'Yes' and 'No': 130 years after the liberation of rabbits, yet another crime may have been committed to deal with the original blunder.

RCD already failing?

Rabbits are distributed over 55% of New Zealand but they are a significant pest only in parts of that range, principally the drier inland regions such as Otago, Canterbury and Marlborough. Faced with falling prices for wool, the impacts of overgrazing, and the removal of government support for rabbit control boards, some landowners have sought new control methods as a solution to their problems. The 'silver bullet' has come in the form of Rabbit Calicivirus Disease (RCD).

RCD was unknown to science until 1983. It was first recorded after it jumped from an as yet unidentified host species to rabbits and caused an epidemic which swept China's wild and domestic rabbit populations[25]. Studies over a 10-year period have recorded a 1-4% change in the RCD genetic code[26].

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[23] Fraser & Speedy (1997)
[24] See King (1984; chapter 4)
[25] O'Neill (1997)
[26] Stone (1997)

The introduction of RCD has been described by the Office of the Parliamentary Commissioner for the Environment as a biosecurity/biocontrol fiasco[27]. MAF's Chief Veterinary Officer decided not to allow the importation of RCD, principally because of:

- the poor understanding of the epidemiology of the RCD virus and the disease it produces;
- the significant uncertainty over the likely effectiveness of the virus as a bio-control agent (as proposed by the Applicant Group) or even as a cost-effective biocidal agent;
- the inadequacy of the biological control management programme proposed by the Applicant Group to deal with the uncertainties and risks (which are now apparent); and
- the uncertainty of the legal basis for the management of the virus.

However, the law (and the lessons of history) were ignored and RCD was illegally imported. The virus was soon deliberately spread throughout the country. This action was particularly ironic given that it is farmers who are probably the most reliant for the protection of their livelihoods on good border control and enforcement of our biosecurity laws.

Like the mustelids before them, RCD may prove to be a big

Rabbits—a cautionary tale

Wild rabbits were introduced into Southland in 1864 and after a few false starts, they began to behave in the way they are renowned for. Before long they were becoming a serious nuisance and began spreading northwards[28]. By the 1870s some stations had their stock numbers reduced by over 60%; from 1878 onwards, immense areas of grazing land were abandoned as the owners gave up the unequal struggle.

The affected run-holders reasoned that rabbits reached such huge numbers in the absence of their natural northern hemisphere predators. The obvious remedy would be to restore the 'balance of nature' (much talked of, but little understood, then or now) and things would return to normal.

The farmers' demand that the government bring in the 'natural enemies' of the rabbit was strongly opposed by naturalists and some of the Acclimatisation Societies. Legislation to prohibit the introduction of polecats (wild ferrets) and other noxious animals was introduced into Parliament; arguments were clearly put that ferrets were unlikely to control rabbit numbers, but would instead have a devastating impact on the native fauna. However, in a process played out time and time again since then, vested interests applied such enormous pressure that the protests were over-ruled and the legislation was rejected.

In the ten years from 1882, hundreds of stoats and weasels, and thousands of ferrets were released on the farmlands most affected by rabbits. The new arrivals were soon found to be slacking on the job. Within a short period came the reports of weasels and stoats spreading into forests far from their release sites, and of drastic declines in native birds in the forests of Westland and Fiordland. The local extinction of kakapo, kiwi, weka, blue duck, bush wren, and so on, was attributed to the arrival of the mustelids from across the main divide. In the North Island, weasels spread north from the Wairarapa *ahead* of the rabbits.

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[27] Office of the Parliamentary Commissioner for the Environment (1998)

[28] King (1984, chapters 3&4)

disappointment as a control agent of rabbits. The effectiveness of the virus appears variable, with the greatest success in the driest areas. Immunity in rabbit populations is of concern. It is likely that the virus will have a cyclical effect on rabbit populations but this has yet to be confirmed. The reasons for genetic defects found in some infected animals is not known.

Many farmers are still using traditional control methods along with the virus. In the meantime New Zealand has a new disease which has already shown an ability to rapidly mutate and to jump species[29]. The virus will be here for all time representing a small, but ongoing, potential threat to both human health and to the health of our native wildlife.

Chinchilla — our latest rodent import

There have been many recent failures, or near-failures of New Zealand's biosecurity system. Controversy has surrounded the apparent lack of both rigour and comprehensiveness of the risk analysis for recent imports. Examples are import applications for the Bengal cat, koi carp, chinchilla, shrimp, deer from New Caledonia, uncooked salmon from Canada, cooked poultry from Thailand, parrots from England — all of which pose particular risks to New Zealand's native plants and animals, agriculture, forestry and fisheries.

The first news most people, or interested institutions, had about the introduction of Chinchilla in 1984 were newspaper pictures. They showed the large rodents being held by one of their importers, accompanied by stories about the huge potential for a new fur industry.

There was an immediate public outcry. This new rodent was known to live in the drier native grasslands of South America — which shares many plant genera with New Zealand, including the tussock genus *Chionochloa*[30].

It soon became apparent that an inadequate environmental impact assessment by the promoter had preceded the approval. Much of the material on which the approval was based was incorrect or incomplete. Faced with mounting criticism, attempts were made to place restrictions on the holding and distribution of chinchilla. These included the requirement that chinchilla be kept in double-fenced enclosures, that they could not be sold as pets and that they were not to be allowed into the South Island. However, it was soon discovered that MAF had no power to impose these controls after the import licence had been approved[31].

Chinchilla farming never took off. Both importers had abandoned chinchillas within 2 years and the animals were sold to pet shops. Chinchillas are now found in captivity throughout the country, including the dry east coast of the South Island. Recently, a chinchilla was spotted in the wild twice, months apart, in Northland[32]. It may be just a matter of time before chinchilla are released either accidentally or deliberately into

[29] Stone (1997)
[30] Hackwell (1984)
[31] Ministry of Agriculture and Fisheries papers released under the Official Information Act
[32] Johnson (1996)

our drier native grasslands, where they may join rabbits in having a devastating impact.

Some regional councils have used their powers under the Biosecurity Act to ban chinchilla. However, the Government has resisted calls for chinchilla to be banned with owners being appropriately compensated. The costs of dealing with chinchilla now may be very small compared to the possible future costs of controlling them in the wild.

The bigger and 'better' moggy

If someone proposed to import a new rat hybrid which possessed genetic material from a vigorous Asian species known for its ability to climb and hunt, there is no way that it would gain approval. Likewise, if someone proposed to import a new hybrid fruit fly which was 93.75% the same as an already established fruit fly species, but included 6.25% of genetic material from a new fruit fly species known as a vigorous pest of horticultural crops, the application wouldn't get past first base.

Yet in 1996 the importation of the Bengal cat — a cross between the domestic cat (*Felis catus*) and the large, forest-dwelling Asian leopard cat (*F. bengalensis)* — was approved without even a formal risk analysis process being carried out and without the involvement of the Department of Conservation in the decision-making process[33].

Bengal cats are bred for four generations to retain as much of their Asian Leopard cat appearance as possible and to have a good temperament towards their owners. Such breeding, which leaves the new cat with 6.25% of the Asian leopard cat's genes, is aimed at retaining their phenotypic (external) characteristics. There is no separate selection to remove their distinctive hunting instincts or abilities, which are different from those of the domestic cat.

MAF revealed that they had relied heavily on the controversial decision of the Australian authorities to allow the importation of Bengal cats into Australia[34]. Taking the lead from Australia raises the question as to how well MAF is placed to make decisions on importations which may have an impact on New Zealand's ecological values. Australia's ecological history is completely different from New Zealand's.

The Australian native fauna has evolved for millions of years in the presence of mammalian predators. Even so, in many parts of Australia, efforts are being made to eradicate cats. What was a controversial decision by Australian authorities, should not have been transferred to New Zealand without adequate checking here.

A deer by any other name?

Another recent example involves the granting of an import licence for deer from New Caledonia. Not only were there inadequate animal health requirements attached to the licence, but neither did the licence specify the species of deer it applied to. If vigilant conservation groups had not picked up what was happening, a new species of deer could have been introduced to the country without any assessment of its potential environmental impact. The deer might have brought with them any number of diseases which could have threatened the existing deer industry and possibly the rest of our livestock industry too.

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[33] Department of Conservation (1997b)

[34] Ministry of Agriculture and Fisheries (1997)

Threats to native bird life

Controls on the importation of birds and bird products are being loosened by the Ministry of Agriculture despite concerns about the disease risk and strong opposition from conservation groups, DOC and the Poultry Industry Association.

New Zealand's geographic isolation has been a boon for native bird life and the local poultry industry. Many serious avian diseases, epidemic in much of the world, do not occur here. Yet many of the controls on avian imports have been portrayed as unnecessary constraints on trade. Pressure is being applied by overseas exporters to open New Zealand's borders to avian imports. Such a move could backfire by introducing avian diseases that would devastate the local poultry industry and native bird life.

There are proposals to import raw turkey meat from Britain and cooked chicken from Thailand. Similar changes to the Irish quarantine requirements for live bird and poultry meat imports resulted in the introduction of many new avian diseases in just 3 years[36].

Killing the kiwi?

It is hard to think of anything more typical of New Zealand than a kiwi. In 1997, an application was made to MAF for an import licence to bring into the country live ratites (ostriches, emus and rheas, which are closely related to kiwi), and their products (hatching eggs and uncooked meat) which placed the kiwi under extreme threat. The regime for importing and quarantining the birds lacked the use of sentinel birds (birds sacrificed for testing) as a risk management precaution[37].

A risk analysis prepared by MAF's Regulatory Authority (MAF RA) ruled out 46 avian diseases on the grounds that there was no available scientific information that they affect ratites. A precautionary approach would have presumed that a danger of potential infection from the diseases existed until ruled out by scientific information.

It defies common sense and good border control management that the onus of proof should be on the global scientific community to demonstrate that ratites can be affected by a disease, before the disease could be accepted as a potential hazard. This stance biases the situation in favour of the importers, because little is known about infectious diseases in ratites and therefore fewer hazards will have been identified than really exist. Ignorance about infectious diseases perversely encourages importers, while increasing risks for everyone else.

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[36] NZ Poultry Industry Assn to MAF on avian imports, 1996

[37] Smith & Grant (1998)

While the ratite importers were seeking to change the status quo, the risk analysis was deficient in demonstrating the relative risks.There must be a consistent approach to the onus of proof which is conservative — in favour of protecting the status quo — because to do otherwise is to favour the possibility of introducing into New Zealand new unwanted pest organisms.

Live plant material—a real threat

A recent review of Australian quarantine alerted to the dramatic increase in the amount of living plant material entering Australia on a daily basis. This comprised particularly cut flowers, and to a lesser degree ornamentals and propagative or seed stock[38]. Import statistics indicate that the same applies to New Zealand[39].

As in Australia, this route of entry for exotic pests and diseases undoubtedly represents a very significant opportunity for quarantine failures for New Zealand. Over half of the listings for Australian pest interceptions were made from imported cut flowers.

The Australian study found that the threat posed by cut flowers arises from the following factors[40]:

- The port of entry is in many instances the only point at which flowers are inspected—potentially too late as they have already landed.
- The sampling level is low, possibly due to the perishable nature of the product. There is similarly a sense for non-destructive inspection, which can lead to pests being 'overlooked'.
- Flowers are 'designed' to attract insects and are subject to infestation by all life stages: some of these are very small, cryptic and can be easily overlooked during an inspection.
- Where consignments of cut flowers are accompanied by Phytosanitary Certificates, these are sometimes of dubious value, especially from certain parts of Africa.
- Where consignors gain a reputation for continually exporting infested shipments, they are able to evade 'black banning' simply by changing their business names.

Live plant imports into New Zealand jumped 308% between 1993 and 1996. Over 364 tonnes of live plants, flowers and foliage were imported in 1996 alone[41]. This single, relatively small industry could pose a significant threat to our biosecurity. The MAF Regulatory Authority have recognised the extent of the potential problems and is in the process of putting together a new standard for dealing with live plant material, particularly cut flowers.

There is good evidence that the insecticide-resistant whitefly, *Bemisca tabaci* (biotype B), and the Western flower thrips *Frankliniella occendentalis* entered Australia on imported plant cuttings and cut flowers. Both insects have wide host ranges and, more seriously, are vectors for plant viruses capable of infecting both native and cultivated plants. Between 1991 and the end of 1994 in the Imperial Valley of California alone, 9000 local jobs had disappeared and crop losses due to whitefly exceeded US$300 million.

Western flower thrips represents a major threat because it is exceptionally aggressive and capable of feeding on not only commercially important plants, but also the native flora. It could introduce the tomato spotted wilt disease to native plants. This could have serious implications for our native flora and would also greatly increase the available pool of infection for cultivated plants.

One strain of Western flower thrips lives only on lupins and has been known in New Zealand for many years. This makes it very important that New Zealand quarantine can identify the differences between the two strains so that should the invasive strain arrive in New Zealand it is dealt with immediately.

38 Australian Academy of Science (1996)
39 Statistics New Zealand (1998)
40 Australian Academy of Science (1996)
41 Statistics New Zealand (1998)

Plant pathogens

Another danger factor of introduced exotic organisms is their role as carriers of microbes. These often unseen companions of introduced species can pose a major threat.

A good example is perennial ryegrass (*Lolium perenne*). A series of introductions over the last 100 years into Australia and New Zealand have inadvertently introduced at least two species of endophytic fungi, an endophytic yeast, bacteria, two eriphyid mites, the ryegrass mosaic and ryegrass cryptic virus and possibly the barley yellow dwarf viruses and some of their aphid vectors.

Economically, the most important introduction has been the perennial ryegrass endophyte (*Aceronium lolii*). This fungus has a major impact on the performance of ryegrass pastures: ingestion of endophyte-infected grasses can be toxic to livestock. Ryegrass mosaic virus (RgMV) was first reported from Australia in 1985 and New Zealand in 1992. There is evidence that vegetative material was illegally imported, bringing with it RgMV and its mite vector[42].

Other close calls of an accidental nature

There have been several recent incidents of border control failures or near-instances of unintentional imports. An Asian ship rat (*Rattus rattus flavipectus*) was found squashed beneath a container from Asia at Port of Auckland[43]. This incident, and recent sample inspections where considerable quantities of soil and numbers of insects were discovered on the base of containers, have highlighted the need for inspecting the undersides of containers — previously seldom done.

Second-hand forestry equipment entering New Zealand has been found to contain forest debris. There have been recent examples of imported second-hand cars, locomotives and other machinery where quarantine checks have discovered soil, plant matter, a snake and any number of insects, including eggs of the gypsy moth — the most serious forest pest in the world not yet found in New Zealand.

There have also been several interceptions of insects which are known as vectors of human diseases, at present absent from New Zealand. Second-hand tyres and a cement mixer were found to contain water infested with Asian tiger mosquitoes. These are capable of carrying dangerous tropical diseases such as Japanese encephalitis and dengue fever. It has been estimated by the Public Health Commission that an outbreak of dengue fever could cost the country up to $250 million. Yet in 1997 a mere $140,000 over 10 years had been allocated for mosquito detection and control[44].

The inadequacy of this low level of funding was highlighted just before Christmas 1998, by the discovery near Napier of the southern saltmarsh mosquito, *Aedes camptorhynchus*. This species is capable of carrying the Ross River virus disease and the rare, but potentially fatal, Murray Valley encephalitis[45]. Well over a million dollars have been spent attempting to control

[42] Guy et al. (1998)

[43] Cunningham & Moores (1997), see also Braunias (1998)

[44] Ministry of Health (1997)

[45] Ministry of Health (1999)

and possibly eradicate the mosquito.

There may well be a further increase in the number of potential pests of our primary production sector which enter the country on both used and new imported vehicles. This is one possibly unforeseen consequence of the recent removal of the last tariffs on imported motor vehicles.

Mosquitos, tussock moths and fruit flies managed to establish despite the surveillance systems which were specifically set up to detect them. What other new organisms may be entering the country undetected, because we are not specifically looking for them?

The uneven playing field

The above are examples of less than rigorous border control when it comes to potential threats to the *natural environment*. They need to be contrasted with the swift action taken by authorities when a tussock moth and a fruit fly both recently arrived in Auckland. In both instances, very extensive, expensive, and intrusive campaigns were carried out to eliminate the infestations before they gained a foothold. Both these potential pests threatened valuable *export industries*....

Can we improve the response of the authorities to potential threats to the natural environment? The answer has to be that we hope so. The Biosecurity Act, and the change in legislation governing the importation of new organisms (the Hazardous Substances and New Organisms Act 1996) plus the establishment of a new regulatory body to implement the Act (the Environment Risk Management Agency, ERMA), provide an opportunity to start afresh. However, little will change unless there is a significant improvement in the consideration given to the protection of the natural environment.

New Zealand's biosecurity and border control

When border control staff are successful, their efforts go largely unnoticed. However, it is important to recognise that the conditions that prevail today are in many critical aspects different from those of past decades.

Greater flows of international trade into and out of New Zealand have resulted from the dismantling of trade barriers through deregulation, tariff reductions and the Uruguay round of GATT (General Agreement on Tariffs and Trade). The value of imports to New Zealand increased by 35% over the period 1990 to 1995. Between 1992 and 1997, the volume of air freight through Auckland and Christchurch airports rose by 45% and 65%, respectively. Between 1990 and 1995, the value of imports from eastern Europe increased by 53%, from south-east Asia by 95% and from southern Asia by 82%. Tourist traffic has also increased dramatically. About 1.3 million international travellers from an ever-expanding list of countries arrive in New Zealand every year[46].

Other new conditions include:

[46] Gerard et al. (1997)

- Through containerisation, refrigeration, and quicker air and sea transport, the survival of 'travelling' pests is more likely.
- There has been a massive increase in numbers and volumes of living plant material entering New Zealand.
- The routes of entry have multiplied and the increased use of containers is injecting pest species deep within the country.
- Global warming, with attendant changes in rainfall patterns and increased temperatures, may gradually be making the environment more favourable for some pests, including vectors of human and animal diseases.
- The ramifications of the GATT have made it much more difficult to restrict trade on biosecurity grounds in the absence of strong scientific and technical evidence.
- As ships increase in size, the disposal of ballast water poses a greater risk of marine pests invading New Zealand's coastal habitats.
- There is a growing demand for the import and export of Genetically Modified Organisms (GMOs); biosecurity services must be prepared to cope with these technical advances.

All biosecurity management should ensure that an adequate consideration is given to plant, animal and human health and to environmental issues. Short-term trade and primary industry resource issues should not be allowed to overrule these broader considerations, which can have long-term or permanent consequences.

Safe trade versus free trade?

The principles of the GATT have profound implications for our biosecurity. Even to restrict the movement of commodities on legitimate biosecurity grounds may not be without cost to a country's reputation in terms of trade. Unless backed by well-justified scientific and technical information, attempts to restrict trade for biosecurity reasons can not be legally blocked. Trade considerations are placing pressure on biosecurity authorities to take greater risks, both technically and philosophically, where such information is unavailable.

Under the new rules of international trade, countries are allowed to protect their interests by erecting technical barriers to trade based on scientific grounds. To meet all of these new and increased threats to New Zealand and its trade, we must have expertise to[47]:

- identify any new pests that appear in New Zealand;
- identify and manage the risks posed by potential and actual pest threats;
- produce eradication, containment or management strategies for any outbreaks — both new to New Zealand and new to a region;
- institute research programmes that assess damage, control

47 Gerard et al. (1997)
48 Gerard et al. (1997)
49 Bright (1999)

and the likely extent of future spread of newly introduced organisms;

- describe the geographical distribution, biology and control of all pests within New Zealand;
- be aware of potential pests, their current geographical distribution, biology and control.

The World Trade Organisation Agreement on the Application of Sanitary and Phytosanitary Measures, and the Sanitary and Phytosanitary Measures and Technical Barriers to Trade Agreement, state such measures. They must be based on sound science, transparent, technically justified, and sufficient only to protect plant and animal health.

Changes in the number of scientists and technicians working on New Zealand biosecurity show that most disciplines have down-sized during the 1990s — at the very time that threats to our biosecurity have been significantly increasing. Biosecurity expertise has been fragmented and spread between Crown Research Institutes (CRIs) and science funding outputs.

It might be regarded that-the CRI structure imposes barriers to collaboration: not only are small teams spread between many research organisations, facilities also suffer below-capacity use and relatively high costs of maintenance and depreciation. Some disciplines are already below critical mass within individual organisations. The requirements of the Technical Barriers to Trade agreement, and the new HSNO and Biosecurity Acts for timely information and technical support, may not be able to be met because of this reduction in capability. By seriously compromising our biosecurity, this in turn may jeopardise our horticultural, forestry and agricultural trade as well as our native biodiversity.

It is important that considerable scientific resources are available to support biosecurity operations through nationwide networks of entomologists, plant pathologists, plant and animal ecologists, weed scientists, veterinary scientists and other experts. However, with the continuing commercialisation of New Zealand science, free or quick access to such expertise is increasingly unlikely; special financial provision will be necessary, possibly on a retainer basis.

The recent inter-agency co-operation to eradicate the invasion of the introduced seaweed *Undaria*, which threatened Stewart Island's conservation values, was exceptional. It relied very much on the personal professional relationships of the people involved. The consensus of those involved in the recent efforts to eradicate the white tussock moth in Auckland was that the programme suffered from a lack of early collaboration, when important questions were not asked and the input was narrow[48]. When time is of the essence, there should be none wasted on deciding who is responsible, or on who should be involved, followed by negotiating contracts.

Container contagion

Containers have been identified as significant pathways for insects, weed seeds, slugs, and snails. One of the most dangerous pests known to be using this pathway is the Asian tiger mosquito (*Ades albopictus*), an extremely aggressive biting pest. In Asia, this mosquito is a major vector of dengue fever, an excruciating disease that gets its common name from the pain it inflicts: 'break-bone fever.' Dengue infects about 560,000 people each year and kills 23,000. The mosquito can carry at least 17 other viral diseases, including various forms of encephalitis and yellow fever. For decades, the Asian tiger mosquito had been a common pest throughout much of the Indo-Pacific region, from Madagascar all the way to Hawaii. Then in the mid-1980s, it embarked on its version of world conquest. It is currently known to have established itself in the south-eastern United States, Brazil, southern Europe, South Africa, Nigeria and Australia. It may have been a contributing factor to the 1986 yellow fever epidemic in Rio de Janerio, in which about 1 million people were infected. The vector of this vector turns out to be the containerised used tyre. Millions of used tyres are traded internationally every year. [49]

The lack of clarity as to who is responsible for co-ordinating this type of work has been identified as a major deficiency in the recently released draft New Zealand Biodiversity Strategy[50]. Such work should be carried out by a new dedicated agency which should also establish strong and sustained links with universities, museums, CRIs, DOC, Regional Councils, iwi, etc. This would ensure that the environmental threats are adequately addressed and resources are available to deal with them should the need arise.

A national co-ordinated program to survey and monitor pests and diseases throughout New Zealand has to be a priority. Most detections currently occur after the pests have established themselves in their particular ecological niche and are reported by affected or interested individuals. We could do much better.

Plans for eradication of new unwanted organisms in New Zealand

Pest plants are recognised in the New Zealand environment at an average rate of two new species a year. These are generally plants which have been known to be in New Zealand for some time. Because of the lag time that occurs between establishment in the wild and realisation of weedy potential, there are already likely to be many, many species poised to become new weed problems in the foreseeable future. Compounding the problem is the fact that weed spread is usually exponential. Minor problems today become major problems tomorrow.

Several factors influence the ease and cost of eradication, including:

- careful assessment of the country of origin and route of entry into New Zealand;
- adequate monitoring and early detection;
- sensitive methods to detect low populations;
- rapid action after detection;
- availability of effective methods of control or eradication;
- public acceptance of control methods.

A comprehensive listing of those plant species that are known to be invasive elsewhere has recently been produced by Landcare Research for MAF. Priority must be given to the completion of a similar list for potential animal pests, including insects. Although such lists may never be complete, they can assist considerably in preventing many importations; they may also assist in identifying species already in the country with the potential to become pests.

Incursion contingency plans must also be prepared for these potential pest species, to ensure that over time 'corporate/institutional memory' is not lost and a speedy, considered response can be assured should the pests establish. Such plans should also cover pests which are present in some regions of the country, but absent from others.

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[50] Department of Conservation & Ministry for the Environment (1999)

Eradication almost always involves the extensive use of pesticides or herbicides. In a few well-researched insect pests, it may also involve mass liberation of sterile males. Critical is the speed of taking appropriate action, before the animal or insect pest or weed has spread so widely that eradication is prohibitively expensive. Readily accessible funding is needed to deal immediately with new pest outbreaks, both at the national and the regional levels.

Once a pest is discovered, another option may appear more attractive than eradication: long-term management to maintain the pest population indefinitely below the threshold at which it causes economic or ecological damage, or to restrict, or delay, its spread to other areas. This would have a far lower initial management cost compared to eradication. However, the cumulative long-term costs of management are likely to be far greater; therefore the feasibility and cost of eradication should always be carefully considered for every new intrusion.

Who should pay?

Failures of biosecurity in the past have led to pest problems which are a massive drain on the economy, to the tune of $960 million a year. To be economically, ecologically and culturally responsible we must take every possible action to:

- prevent the establishment of new potential pests and diseases in the New Zealand environment, and
- eradicate or effectively control those pests and diseases which are already here.

These actions represent a substantial cost to the country. But the expenditure will save the country significantly more in the long term. How can these costs be met? Those benefiting directly from activities which create potential risk, such as trade and travel, should meet much of the cost of border inspections.

1. 'Unintentional' introductions

Many routes for unintentional introductions are possible. The main routes are where the organisms hitch a ride in products imported into the country, or where they arrive on the ships or planes which bring both people and produce. When organisms arrive by these routes, the risk of border control failure is borne not by the importer or the carrier, but by the whole country and possibly for a very long time. For this reason the scrutiny of imports and the surveillance against unintentional importations must be of the highest possible standard. The cost should therefore be borne mainly by the State. Even so the State should have regimes that encourage importers and carriers to take the upmost care, and that penalise them severely if they do not.

It is a concern that, in an effort at cost cutting, New Zealand may allow more reliance to be placed on quality assurance of fumigation and inspection in the country of origin. This has a potential for major failure: overseas work may be undertaken at the lowest price, and regulations may not be followed and corners cut.

The recently released draft New Zealand Biodiversity Strategy 'Our Chance to Turn the Tide' recommends goals that will do little more than just hold the line of native species extinctions over the next 20 years. These surprisingly modest goals are costed at around an extra $46 million per year for a range of initiatives: biosecurity and pest management are only part of these[51].

A more ambitious set of goals would see a 'turning of the tide' with a vigorous biosecurity regime, dealing with existing and potential pest species. This would not only assist the recovery of many threatened native species and degraded natural ecosystems, but would also benefit our economy.

Oil pollution versus biotic pollution

When the fishing boat *Dong Won* ran aground on Breaksea Islands off the south-east coast of Stewart Island, it created New Zealand's largest-ever oil spill.

Prior to the oil spill there was already a marine oil spill response plan, and resources were ready to be flown into the area. Special facilities for dealing with oiled wildlife had been set up. Clear responsibilities for co-ordinating the response to the spill had been established in advance. Within a few months of the spill, the company responsible for the fishing boat had already paid compensation to local fishers who were affected, and is expected to pay a bill of nearly $1.5 million for the emergency response and clean-up costs[52].

It is instructive to compare the official reaction to this environmental disaster with the reaction to the discovery of the introduced seaweed *Undaria pinnatifida* in nearby Big Glory Bay.

Despite the fact that the introduction of a pest such as *Undaria* could have massive long-term environmental and economic impacts, there was no contingency plan in existence for dealing with such a pest. When *Undaria* was first discovered there was much confusion as to whose responsibility it was to deal with it. There were no pre-arranged dedicated resources or funding available to immediately deal with the infestation. The organisation that caused the 'biotic spill' is very unlikely to be prosecuted or held responsible in any financial way for the costs of the eradication programme which has now been implemented.

2. Deliberate importation

There can also be a major cost of protecting New Zealand primary production from foreign pest organisms that arrive through deliberate importation. In such instances an individual importer may benefit in the short term, but the long-term costs of negligence are borne by the whole industry and the country. An example could be the recent importation application for unspecified deer species for farm stock from New Caledonia. If such deer carry diseases hitherto absent from New Zealand, the costs are likely to be borne by the whole deer industry rather than the individual who benefits from the importation. Likewise the importation of uncooked poultry meat may introduce diseases which severely reduce the existing poultry industry's profitability.

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[51] Department of Conservation & Ministry for the Environment (1999)

[52] Dominion, 28 January 1999

The bio-safety of intentional introductions should be ensured, through comprehensive risk and environmental impact assessments, prior to any decision to introduce an alien species. Assessing the likelihood that an organism may establish in the wild is a notoriously inexact science. Application of the precautionary principle would suggest that no alien species should be introduced to the country or a region, unless it is a matter of national importance to do so; and only if escaped feral populations will not survive or will not threaten native ecosystems or species. The assessment would also provide a containment/eradication plan should the introduced species become a pest.

Monitoring introductions and their impacts after release is essential. The cost of such monitoring should be borne by the importer — in much the same way that the cost of monitoring a resource consent under the Resource Management Act is borne by the consent holder. Where a new introduction (intentional or unintentional) poses a perceived threat to biological diversity, lack of full scientific certainty should not be used as a reason for time-wasting in-action. Speed is crucial for halting new invasions at an early stage whilst they can still be easily and relatively cheaply dealt with.

In these situations, a good case can be made that the importer should bear some of the costs of dealing with the pest problem. Fees are typically structured to raise revenue, not to recoup damages or to change people's behaviour. In this regard all successful applicants should have to post a bond — in the same way that under the Resource Management Act some resource consent holders (such as mining companies) have to post bonds for high-risk activities.

Alternatively, successful applicants might be required to take out insurance to cover the costs of dealing with their organism establishing as a pest. Such 'market' mechanisms could certainly help to inject some realism into dangerous applications which are driven by promises of high commercial returns to the individual promoters, but create potentially high costs to the country's taxpayers and the environment.

3. Meeting external quality criteria

A third type of cost is linked to ensuring that New Zealand produce meets the quality criteria of other countries, in order to maintain lucrative export markets. These costs can be largely, if not entirely, recovered from the exporter, who benefits from selling a product which is considered 'clean' and depends on New Zealand's reputation as a clean, green country.

Playing our role in international biosecurity

In September 1997, the issuing of new import licences for New Zealand timber to enter the United States was banned by a US Federal Court on phyto-sanitary grounds: there were fears that the timber could infest US forest with new pests and diseases. Inspections had shown high levels of fungal and other infestations on the export logs[53]. Although New Zealand exporters and the Government objected to the ban, there is little doubt that both would have argued for similar bans in case of attempts to import timber in the same condition into New Zealand.

New Zealand has also been the country of origin for the export to the USA of possums, wallabies and hedgehogs. Each of these species are pests which do a considerable amount of damage in the New Zealand environment. We should act on our international biosecurity responsibilities and legislate to ensure that potential pest species cannot be exported from the country, except to their country of origin.

New Zealand has a special interest in the protection of Antarctica's biota. Evidence has come to light recently that diseases are being introduced into the Antarctic environment by poor quarantine control: penguins have been infected with diseases of domestic poultry[54]. We should advocate for strict international quarantine to protect Antarctic wildlife. As a first step we should police such a quarantine regime for all goods and people travelling to Antarctica from New Zealand.

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[53] Lack (1996)
[54] Gardner (1997)

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By Geoff Bertram

The impact of introduced pests on the New Zealand economy

Abstract

The loss of output suffered each year by the New Zealand economy due to the existing level of pest infestation is provisionally estimated as $400 million. To prevent the level of infestation from increasing, another $440 million is spent each year by the private and public sectors on pest control. The sum of these two figures, $840 million, represents the directly quantifiable impact of pests on the New Zealand economy.

To this must be added intangibles such as intrinsic values and option values associated with pest damage to the conservation estate, the threat of extinction which pests pose to our indigenous flora and fauna, and threats of potential future entry by new pest species.

The quantified cost of pests to the New Zealand economy is around 1% of GDP per year, plus intangibles.

1. Introduction

The literature on evaluating the economic impacts of biodiversity changes is still in its infancy[1]. Introduced species represent an increase in biodiversity at the same time as they pose a threat to indigenous ecosystems and hence reduce biodiversity. In New Zealand, large numbers of introduced species have positive economic value for the (also introduced) human population. Most pasture and crop species, along with domesticated animals, are non-indigenous. 'Pests' can be defined as those introduced species whose impact on the welfare of the human population has turned out to be negative.

Pests thus represent the inescapable down-side of the large-scale experiment in colonisation of the empty ecological niches of pre-settlement New Zealand.

Many species now regarded as pests were introduced originally in the hope of positive economic gain; examples are rabbits, possums, deer, goats, gorse, thistle, blackberry. Others, such as ship and Norway rat, mice, pasture weevil and other insect pests, arrived accidentally rather than by design - but still as a consequence of settlement. Once established, pests present the dilemma of whether to eradicate or control them. Generally speaking, eradication is very costly and has been regarded as not cost-effective, except in specialised settings such as island habitats for indigenous species recovery programmes. Pest control has been a major feature of public-sector activity in New Zealand for the past century, and most pest populations are reduced in size, but not eradicated, by public spending programmes.

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[1] Norton 1986; Perrings et al. 1994.

The measurable economic cost of pests therefore has two major components:

- **defensive expenditures:** the financial cost of resources devoted to restricting pest populations; and
- **foregone economic output**: the economic output which is foregone each year as a result of the existing level of infestation.

We shall address separately these two components of quantifiable costs.

A third category of economic impacts of pests is less easy to quantify in any unambiguous way, but is obviously important to bear in mind. This is the welfare loss caused by the existence of pest populations (controlled or uncontrolled) over and above their direct impact on commercially productive activities. An example is the ongoing damage to the indigenous forest estate caused by possums, deer and goats. The level of this damage is restricted by the present level of defensive expenditure on pest control, but damage continues because of the decision, consistently made through the political process over many decades, that control rather than eradication is the purpose of such expenditure. Since the conservation estate is, by definition, largely held out of marketed production (except for its indirect use for recreation and tourism), these foregone values attributable to the continued presence of pests can be measured only indirectly - for example, by contingent valuation surveys seeking to measure so-called existence value of indigenous species and ecosystems. Research on these values in New Zealand is not at present sufficient to enable any reliable quantification.

This paper takes a narrowly anthropocentric view of the issue of introduced species. The costs and benefits discussed are those of relevance to the human population of New Zealand, and no attempt is made to engage in valuation of any 'intrinsic values' of New Zealand ecosystems.[2]

2. The Value of Pest Control: Concepts

'Economists have long recognised pest populations as detrimental common property resources.... Many have focused their attention on some of the economic aspects relating to economic thresholds ..., pest resistance ..., and pest-predator relationships. Others have used various optimization methods to solve single-season pest management problems.'[3]

Common property resources possess the characteristics of 'public goods', namely that they are non-rival and non-excludable. Non-rivalry means that the benefits and damages arising from existence of the resource are captured equally by at least wide segments of the human population. Non-excludability means that public benefits or detriments are inescapably consumed collectively, not individually, so that the value of those benefits/detriments to individuals cannot be measured directly by means of prices established in a private market.

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[2] Economic debate over intrinsic value can be found in, for example, Part II of Norton 1986. The concept appears also in the Resource Management Act.

[3] Regev et al. 1976, p.186.

Freedom from pests is a public good[4]. Pest control, consequently, is akin to other activities whose effect is to preserve environmental quality.

Private markets will under-provide public goods, and hence will under-control public detriments. This is because the quantity of environmental protection undertaken in a private market will be determined by the threshold volume that can be financed by the individual or private group with greatest 'willingness to pay' for that work. Quantities above this threshold will be provided only if demand is expressed collectively on the basis of the aggregate willingness of the population to pay (through the use of taxes or rates). Collectively-expressed demand will call forth a larger quantity and usually place a higher value on the service such as pest control.

To measure the public value of environmental services such as pest control, environmental economists have devised a variety of techniques for measuring willingness to pay (WTP) and so-called 'willingness to accept' (WTA)[5]. Four valuation methods in common use:

- 'contingent valuation' relies on individual responses to questionnaire surveys about the value placed on a public good;
- 'hedonic pricing' measures price variations in markets for private goods whose benefits are affected differentially by the public good in question[6];
- travel-cost valuation measures the willingness of individuals to pay to visit particular environmental assets;
- the production-function approach measures the effect of an environmental externality on production possibilities, often by measuring the expenditure which individuals are willing to undertake to avert damage (so called averting expenditure).

The first three of these were not used for the present study because the data were not available. In principle studies using these approaches could be devised and applied to measurement of the impact of pests, but in practice published New Zealand work of sufficiently wide scope was not available for assessing the impact of pests at the macro level. Hedonic pricing, for example, could be applied to data on farm prices in areas heavily affected by pests relative to those in areas not affected. However, New Zealand-wide studies along these lines could not be located.

Generally speaking, it is the production function approach and the measurement of defensive (averting) expenditure that offer the best means of quantifying the impact of pests in New Zealand. Given that pests typically reduce agricultural productivity, the immediate economic impact of the existing pest populations can be measured by the quantified loss of agricultural output valued at relevant market prices. To these losses incurred at the prevailing level of control of pest populations, we can add the amount which individuals and society combined are willing to pay for the existing level of control.

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[4] Meister and Wilson-Salt 1993, pp. 296-297.

[5] For a good survey and references to the extensive literature, see Hanley and Spash 1993, Chapters 3-7.

[6] For example, holding all other variables constant, housing closer to a noisy airport will command a lower price than housing far away; this price differential measures the economic cost of the noise.

Because expenditures by private individuals are generally motivated only by private benefits, individual agents will not take into account the wider benefits to others of pest control expenditures, and hence will tend to under-provide in the fashion that is usual for public goods. Private willingness to pay for local pest control provides a measure only of the private benefit from defensive expenditure. For example, the chance of an individual farmer being able to eradicate a widespread pest, or even have a measurable impact on its reservoir population, are very remote. Individual farmers will spray their own properties to restrain gorse and blackberry but are not in a position to prevent re-infestation from other properties in the neighbourhood. Similarly, individual farmers can limit encroachment of possums onto grazing land by local trapping and poisoning activities, but cannot eliminate the reservoir population in adjoining bush country.

Thus private expenditure will be carried only to the point where the benefit from greater degrees of control is outweighed by the opportunity cost of additional resources, diverted to pest control from other valued uses.

To come closer to socially optimal levels of control, collective action and expenditure are required. Public-sector expenditure on pest control is additional to private expenditures and generally (though not always) complements them.[7] As with private expenditures, public expenditure will not be carried beyond the level at which the perceived benefits of further control effort fall below the costs of additional control.

This discussion clarifies the three steps to be followed in quantifying the economic impact of pests. In the first stage, we assemble figures on actual defensive expenditure by both the public and the private sectors, and take these as indicating the willingness-to-pay to restrict pest populations to the existing level[8], given that pests have already been introduced.

In some respects the observed level of these expenditures goes beyond simple environmental maintenance. For example:

- There is some expenditure devoted to changing the status quo by eradicating pests from selected areas, and restoring threatened indigenous species. Insofar as these efforts are successful, the expenditures are a form of investment as distinct from the ongoing maintenance character of most pest control expenditures.
- There is an area of expenditure on border controls and quarantine services which is akin to the payment of insurance

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[7] The extent to which it is legitimate to add together public and private expenditure to obtain an estimate of total willingness to pay is a difficult issue. Over some range, the two types of expenditure are complementary and hence each secures more benefit than it costs when undertaken in tandem with the other. There will also, however, be areas where the two are substitutes or where one is redundant in the presence of the other. The recent private introduction of calicivirus in an attempt to eradicate rabbits, for example, pre-empted opportunities for possibly more effective publicly-controlled release of the virus, and may thus have been counter-productive, in terms of the effectiveness of public expenditure in this area.

[8] Government spending is a good indicator of society's willingness to pay only to the extent that the political process works effectively to reveal collective preferences. Generally speaking, the longer the time span considered, the more reliably the outcomes of democratic political decision-making should reflect those preferences. Direct Central Government involvement in pest control in New Zealand now spans half a century and eighteen general elections since the mid 1940s. The general order of magnitude of pest control expenditure reflects the outcome of enough debate (and enough turnover of individual decision-makers) to justify the claim that New Zealanders' willingness to pay has been revealed. Similar comments apply to regional and local government as minor partners in public-sector expenditure.

premiums against catastrophic events; thus these expenditures are a means of confronting risks and uncertainties, rather than of holding existing pest populations at a tolerable level.

Having assembled pest-control expenditure data, in the second stage of analysis we attempt to quantify the ongoing losses of production associated with the tolerated level of pest populations in New Zealand. Given that control rather than eradication is the aim of most prevailing defensive expenditure, there will be a set of economic costs which are less than the perceived economic cost of eliminating the pests responsible, but which are nevertheless real costs borne by the economy. Thus foregone output can be added to observed defensive expenditure to provide a total quantified economic cost.

A third stage of quantification, on which progress was not possible given the present state of research, would be the contingent valuation of intangible values foregone as a result of pest damage to the conservation estate and its indigenous ecosystems. The distinguishing feature of the conservation estate is that it represents areas which are held out of economic exploitation for productive purposes (except for some recreation and tourism activities) and which embody environmental characteristics which are of value to the human population in the sense of enhancing the subjective welfare of New Zealanders. These values are, however, non-marketed and hence not susceptible of direct estimation. To the extent that collective willingness to pay for control matches the benefits from control, the first stage of our analysis will capture the cost of holding pest populations to the status quo. However, as with directly productive land devoted to agriculture and forestry, the conservation estate has suffered a reduction in its value due to continued existence of controlled pest populations. This set of foregone environmental values is part of the overall economic impact of pests, although we have not been able to quantify it satisfactorily.

3. Defensive Expenditures: the Economic Cost of Holding the Line

In this section we assemble data on the expenditure undertaken by central and regional government, and by private agriculturists, to limit the impact of pests on the New Zealand environment. This expenditure we take as a conservative estimate of total willingness to pay to maintain the status quo: that is, to prevent the existing balance between pests and the human economy from deteriorating further. Only a small part of the expenditure discussed in this section is aimed at eradication of any introduced species[9].

The bulk of defensive expenditure is for the purpose of control, not eradication — spraying and clearing gorse, blackberry, thistle and other weeds on productive land; restraining growth in possum and rabbit numbers; researching various control methods; and so on. We find that averting expenditures are

[9] The $14 million spent annually by the Department of Conservation on endangered species and island habitats is the main example of an attempt to change the balance (in favour of indigenous species) rather than hold the line.

around $440 million dollars annually, nearly 0.5% of GDP.

Empirical information on weed and pest control costs is not readily available in New Zealand and is widely scattered among a variety of sources. The starting point is Central Government expenditure.

3.1 Central Government

Since 1997, Government expenditure on pest control has been concentrated in two Votes in the annual *Estimates*: Biosecurity, and Department of Conservation. Prior to that year, expenditures were spread across the departmental appropriations of the Ministries of Agriculture, Forestry, Fisheries, and Conservation. Table 1 assembles estimates[10] for actual expenditures by department for June years 1991-98, and the estimates for June year 1999. (For 1998 and 1999, Vote Biosecurity has been allocated across the departments to which funds were allocated for spending.)

Not all relevant Government expenditure is clearly identified in the annual *Estimates* tables. Policy advice, for example, has been costed separately only for 1998 and 1999; prior to 1998 it was simply bundled with general departmental policy advice, and is probably therefore missing from Tables 1 and 2 (except possibly in 1991 when $15.4 million, GST-inclusive, was spent in the Ministry of Agriculture and Fisheries on 'New Pest, Disease and Waste Management Processes and Systems'; this accounts for most of the large 'other' category in Table 2 for that year). Similarly, expenditure on control of TB vectors has been separately identifiable only since the mid-1990s. A major switch has taken place since 1996 from direct delivery of control services to contracting-out of border inspection, animal quarantine, plant quarantine, animal surveillance, plant surveillance, and exotic pest and disease response. This change in mode of service delivery is not apparent in Table 1 since the letting of contracts is still undertaken by the departments shown, funded from Vote Biosecurity.

Inclusive of GST, total expenditure by Government on pest management and control amounts to roughly $150 million per year, or 0.16% of GDP[11].

One other area of central Government spending not included in Table 1 merits attention here. Besides direct spending on pest management, the New Zealand Government also funds a wide range of research into pest-related topics, much of it through the Foundation for Research, Science and Technology. Again, data are not readily available to allow identification of pest-related research funding[12]. A review of 1997/98 contracts[13] for plant pest and biosecurity-related research under the Public Good Science Fund and the Marsden Fund identifies $26 million of public-good research funding for that year, to which would have to be added animal pest-related contracts, suggesting that $40 million per year is a reasonable total estimate.

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[10] Assembling Tables 1 and 2 has required considerable manipulation of the figures given in the annual *Estimates* in order to bring them into a consistent form across the nine years. The two main adjustments required were (i) disaggregation of aggregated figures to exclude non-pest-related expenditure, which has been done by applying ratios derived from years in which disaggregated data was provided for the relevant departmental spending category, and (ii) adjustment of figures to give consistency with regard to GST. Further work was required to allocate expenditure by activity, given the frequent changes in the classification systems used in the *Estimates*.

[11] The GDP measure used is at market prices; hence the GST-inclusive figures are the relevant ones to use. New Zealand's GDP for the year to March 1997 was $95.816 billion. (Dept of Statistics).

[12] In 1990/91, the *Estimates* show the former DSIR spent at least $9 million on 'new and improved pest and disease management processes in primary production and the natural environment', in addition to which there would have been substantial pest-related expenditure concealed in other general DSIR expenditure categories. Thereafter the *Estimates* provide no figures on research funding by purpose.

[13] Gerard et al. 1997, pp. 30-32, 34-36.

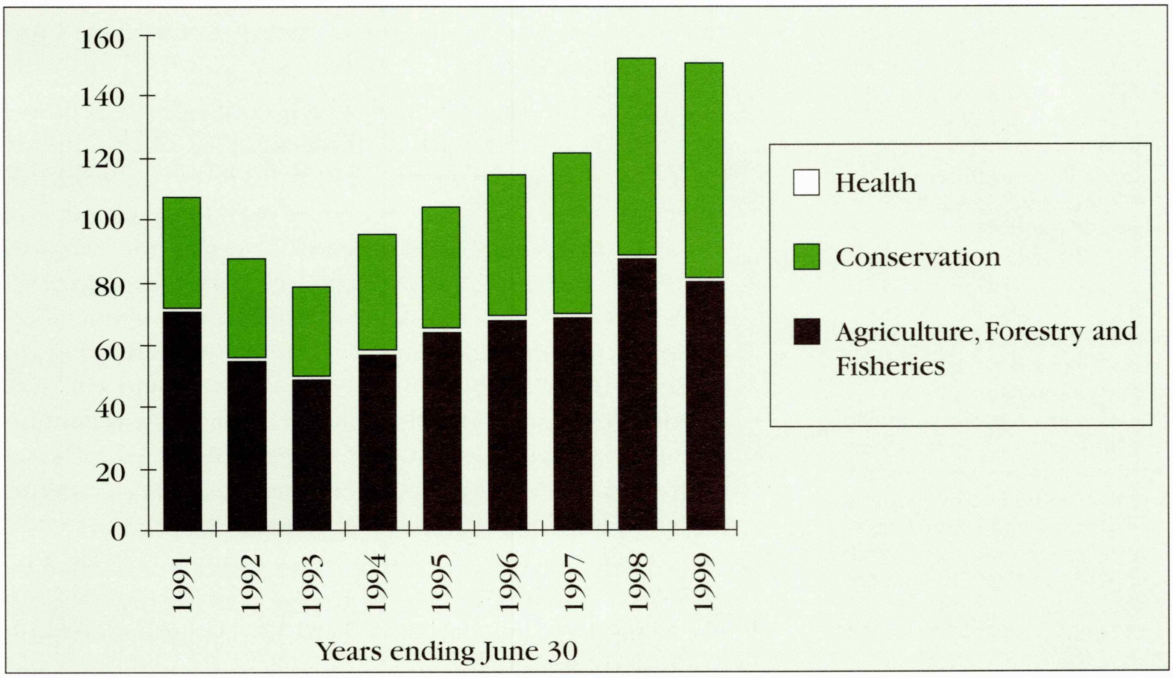
Table 1: Identified Central Government Pest-Related Expenditure by Department, 1991–1999

$ million inclusive of GST*

Years Ending 30 June	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Agriculture & Fisheries	64.5	51.3	45.0	51.8	59.0	61.7	55.8		
Agriculture & Forestry								87.1	80.1
Fisheries								0.8	0.8
Forestry	6.6	4.2	4.1	5.3	5.9	6.2	13.0		
Conservation	38.2	33.9	30.4	39.6	41.1	47.2	53.9	65.0	70.5
Health								0.2	0.2
Total	**109.3**	**89.4**	**79.4**	**96.7**	**106.0**	**115.1**	**122.7**	**153.0**	**151.5**

*To obtain figures exclusive of GST, subtract one-ninth from the figures in the table.

Figure 1: Pest-Related Central Government Expenditure, 1991–1999



Thus a reasonable estimate of Central Government averting expenditure on pests appears to be as follows:

	$million
Ministries of Agriculture, Fisheries & Forestry	85
Department of Conservation	70
Research funding	40
Total	**195**

3.2 Regional Councils

When they were set up in 1989, the new Regional Councils absorbed the previous Pest Destruction Boards and Noxious Plant Authorities, along with their roles. Through the 1990s, therefore, pest control has been an important activity of regional government and expenditures have been recorded in Annual Reports.

Unfortunately, accounting conventions differ widely between councils and from year to year within councils, so that construction of consistent data series for expenditure proved difficult. Issues of particular concern are:

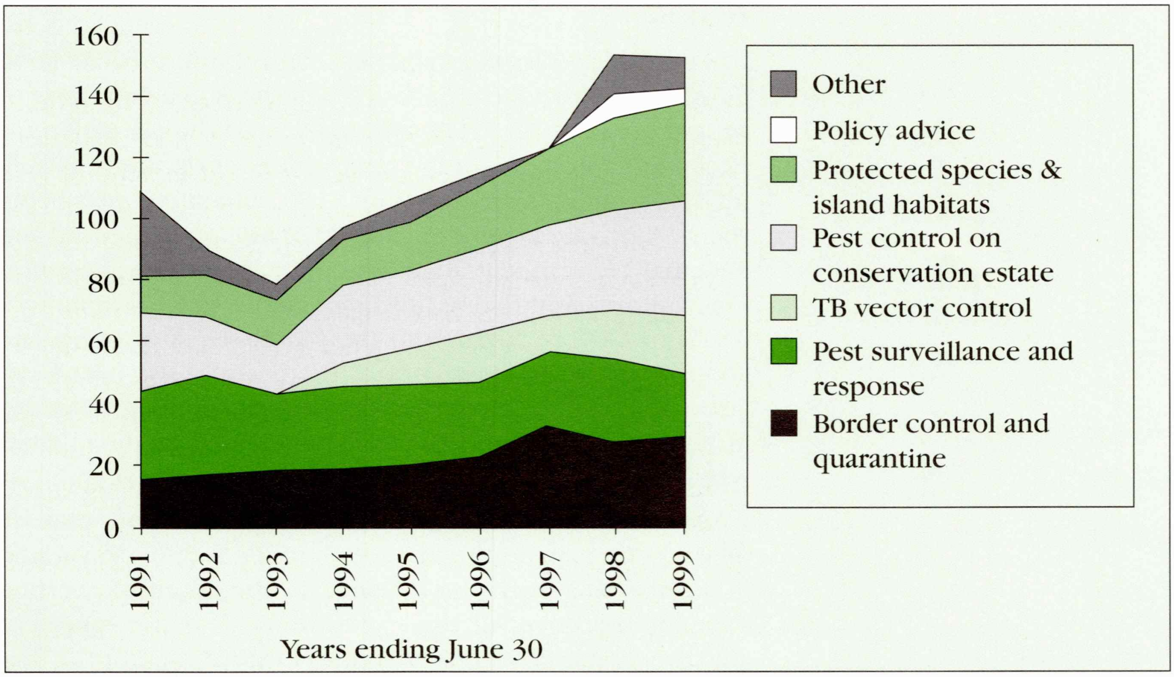
- Council expenditures on pest control are recorded in a variety of forms, many of which do not correspond to the primary information needed for the purpose of this study. The relevant information is the directly-attributable cost of pest control as an activity incremental to all stand-alone Regional Council spending. (This measure gives the actual commitment of resources to pest control by councils whose core business lies in other areas, so that the existence of Regional Councils themselves is not premised on their pest control activities.) A number of council annual reports, however, give expenditure figures which are inclusive of allocated common costs (overheads) of the council. In several cases the figures also include financing costs such as interest payments and debt repayments, and the accounts do not always provide sufficient detail to exclude these.
- Another accounting practice which conceals the required information is the reporting of the 'net cost' of activities to the council rather than the actual direct expenditures incurred. In some cases the procedure used to derive net cost seems to make very little difference, so that the resulting figures can be treated almost as direct expenditures. In other cases, however, net cost is measured as the amount of expenses to be funded from general rates, after deducting any revenues obtained from user charges, as well as grants from Government and payments received by councils as contractors to bodies such as the Animal Health Board (which currently purchases possum control from Regional Councils under contracts funded through Vote Agriculture).
- A third problem is the detail of those sources of finance for Regional Council spending. Insofar as pest control expenditure is funded by levying direct charges on users of council services or from rates, that expenditure represents a com-

Table 2: Identified Pest-Related Central Government Expenditure by Activity, 1991-99:

$ million Inclusive of GST (12.5%)

Years Ending 30 June	1991	1992	1993	1994	1995	1996	1997	1998	1999
Policy advice								8.0	5.4
Border control and quarantine	17.5	18.2	18.7	19.5	20.6	22.9	32.0	28.1	29.2
Pest surveillance and response	24.8	29.9	23.7	25.6	24.4	22.9	23.8	25.8	20.0
TB vector control	0.2			8.3	12.8	17.4	13.0	16.3	19.3
Rabbit and land management	4.5	2.8	1.6		3.1				
Pest control on conservation estate	26.8	19.4	15.1	24.5	24.9	26.7	28.5	32.4	36.1
Protected species & island habitats	11.3	14.5	15.3	15.1	16.2	20.4	25.3	30.3	32.1
Agricultural security	2.7	2.8	4.2	3.1	3.3	3.9			
Noxious plants control	1.0	0.5							
'Pest management'	1.3		0.8	0.6	0.7	0.8		1.8	2.0
Other	19.2	1.3	0.0	0.0	0.0	0.0	0.0	10.2	7.4
Total	**109.3**	**89.4**	**79.4**	**96.7**	**106.0**	**115.1**	**122.7**	**153.0**	**151.5**

Figure 2: Central Government Pest-Related Expenditure by Activity, 1991–1999



mitment of regional resources. However, insofar as expenditure by Regional Councils is funded by grants, subsidies and contract payments from central Government, that Government funding must be subtracted from total expenditure to avoid double-counting, given that those payments have already been included in Tables 1 and 2. Thus ideally we need to start with a figure for all direct avoidable pest-related spending by each council, and then subtract funding from central Government in order to obtain the net resources committed by regional government per se. This separation of the function of regional government as a funder from its closely-related function as an agent of central Government, especially in relation to possum control, presents a substantial analytical challenge.

The results of a survey of Regional Council annual reports for the June years 1991-98 appear in Table 3. Regional Councils spend over $40 million per year on pest management, of which roughly $20 million is funded from central Government, leaving $20-25 million of additional resource commitment by the regional level of the public sector.

Total central and regional public-sector expenditure on pest control is thus about $220 million per year, to which should be added some further expenditure by City and District Councils (this is, however, only small scale).

3.3 Private Sector

The private sector also undertakes substantial expenditure on control of animal and plant pests. The Agricultural Production Account in the New Zealand System of National Accounts provides an itemised table showing the purchases of intermediate goods by agriculture as a whole. Table 4 shows the breakdown of these non-factor costs of agriculture for the June years 1990-95.

In the mid 1990s, 'weed and pest control' intermediate-good purchases were a steady 3.0–3.5% of the non-factor costs of agriculture, at about $180 million per year. The private-sector expenditure was thus of the same order of magnitude as Central Government spending. With $180 million per year being spent by private agriculture and $220 million by Central and Regional Government, total ongoing control and mitigation expenditure identified to this point comes to $400 million or 0.42% of GDP. In addition to the purchases of intermediate goods for weed and pest control, there would also have been direct labour and capital costs of the corresponding activities in agriculture, which we are not able to measure directly but which would be included in a complete accounting.

Apart from agriculture, Nugent and Fraser[14] note that annual private expenditure on deer hunting is $20 million, and in a sense this might be included in the count of averting expenditure. However, this expenditure does not represent any diversion of resources from other valued uses for the pur-

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[14] N & F 1993, p. 361.

Table 3:
Regional Council Spending on Management of Animal and Plant Pests

Total Expenditure, $000

June years	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Northland	*1,000*	*1,200*	*1,400*	1,592	1,725	1,912	1,746	1,634
Auckland	956	1,279	1,306	1,652	2,089	1,901	*2,000*	*2,000*
Waikato	2,614	2,909	3,043	3,463	4,581	4,072	5,881	6,807
Bay of Plenty	*1,200*	1,334	1,690	2,062	1,938	2,025	2,155	2,309
Gisborne	*500*	522	506	460	442	450	495	590
Taranaki	684	681	900	1,211	*1,277*	1,342	1,532	1,585
Hawkes Bay	1,620	1,435	1,813	2,349	2,302	2,357	2,490	2,456
Manawatu-W'ganui	2,952	3,912	3,733	4,090	4,959	5,251	*6,418*	*7,256*
Wellington	*1,000*	*1,270*	1,405	2,120	2,926	3,216	4,723	*4,500*
Marlborough	*1,000*	1,430	524	804	730	688	707	*700*
Tasman	*	*	*400*	318	655	648	827	1,004
West Coast	276	185	536	1,368	1,222	1,486	1,500	1,500
Canterbury	*2,500*	2,460	5,338	4,829	7,688	5,551	4,504	4,368
Otago	6,910	5,716	5,776	5,386	6,420	3,462	3,230	3,751
Southland	*1,700*	1,790	1,735	1,912	2,223	3,012	1,940	3,316
Total	**24,912**	**26,123**	**30,105**	**33,616**	**41,177**	**37,373**	**40,148**	**43,776**

Estimated Expenditure Net of Government Grants, Subsidies and Contracts

June years	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
Northland	*1,000*	*1,200*	*1,400*	1,592	1,725	1,912	1,746	1,634
Auckland	956	1,279	1,064	1,303	2,059	1,901	*2,000*	*2,000*
Waikato	2,290	2,087	1,932	1,460	623	192	361	1,739
Bay of Plenty	*1,100*	1,286	1,611	1,651	1,604	1,774	1,987	2,183
Gisborne	*500*	522	506	460	442	450	495	590
Taranaki	684	681	900	1,211	*1,103*	1,263	1,518	1,585
Hawkes Bay	1,471	1,435	1,813	2,005	1,869	1,942	1,875	2,042
Manawatu-W'ganui	2,250	3,062	2,955	2,863	2,656	2,691	*3,000*	*3,500*
Wellington	*600*	*1,000*	1,034	1,210	1,562	2,260	1,737	*1,700*
Marlborough	*800*	1,113	503	471	504	444	566	*500*
Tasman	*	*	*400*	314	291	447	591	562
West Coast	276	53	311	339	0	0	0	0
Canterbury	*1,500*	1,484	4,010	3,545	6,230	4,859	3,776	3,368
Otago	3,376	3,384	1,751	2,591	3,309	1,278	1,025	1,068
Southland	*1,700*	1,760	1,618	1,701	1,643	2,313	1,039	988
Total	**18,503**	**20,346**	**21,808**	**22,716**	**25,620**	**23,726**	**21,716**	**23,459**

* Tasman included in Marlborough 1992.

Italicised numbers are interpolated, extrapolated, or guessed.

pose of pest control, since the primary reason for hunting is recreational. The control of feral deer numbers due to an annual harvest of 70,000 deer from a wild population of 250,000 is an incidental by-product of hunting as an activity, and the $20 million figure represents the value of recreational hunting itself. This expenditure is therefore excluded from our cost estimate.

Several areas of public and private sector spending related to pest control and damage mitigation are not included in the figures above. Obviously most households in New Zealand incur costs to control insect, animal and plant pests in both house and garden, and in the aggregate these expenditures are likely to be quite substantial. If, for example, New Zealand's 1.1 million households average $20 per year of pest-related spending, this would add $20 million to our figures here while accounting for about one-twentieth of one percent of household spending[15]. Local government spending on control of pests in parks and reserves, similarly, is too small to be separately recorded in annual accounts but would probably add up to some millions of dollars annually nationwide. Labour and capital employed in agricultural pest control, as already noted, are missing from the $180 million figure above. Costs of clearing water weeds from lakes, rivers, irrigation channels and drains are also substantial. Overall it seems reasonable to add at least 10% to our earlier $400 million figure in order to account for these and other unmeasured items, giving a total estimate for defensive expenditure of $440 million (0.46% of GDP).

Table 4:
Agricultural Sector Purchases of Intermediate Goods, $ million

	1989/90	1990/91	1991/92	1992/93	1993/94	1994/95
Purchase of livestock	685	592	625	804	815	581
Feed and grazing	372	368	374	509	491	544
Animal health and breeding	250	266	275	338	359	348
Weed and pest control	**151**	**147**	**159**	**197**	**179**	**178**
Fertiliser, lime and seeds	613	585	663	864	846	788
Fuel and power	343	346	354	384	350	387
Repairs and maintenance	704	695	704	811	794	689
Freight	146	152	150	164	158	158
Other	1,468	1,448	1,501	1,628	1,861	1,836
Total	**4,733**	**4,599**	**4,806**	**5,699**	**5,854**	**5,511**
Less capitalised development	19	20	19	15	25	23
Total intermediate purchases	**4,715**	**4,579**	**4,787**	**5,684**	**5,829**	**5,488**

[15] Pest-related spending lies below the threshold for separate treatment in the Household Economic Survey. That threshold is roughly 0.1–0.2% of spending.

4. Production Losses: Foregone Output Due to Pests

In this section, we turn to direct economic costs in terms of the loss of production in agriculture and forestry attributable to the presence of introduced pests. We estimate that losses in the form of foregone production are of the order of $400 million per year, approximately the same again as defensive expenditures.

Besides defensive expenditure actually undertaken by Government and private agents - reflecting respectively revealed collective and private willingness to pay for pest control and restoration of damaged environments - there exists a certain amount of information on the estimated economic damage directly attributable to introduced pest species. This is damage which accrues alongside the existing level of mitigation expenditure, and hence can be added onto it in constructing a total damage estimate, although the two types of measure are different in important respects. Expenditure figures reflect resources actually committed, and hence diverted from alternative uses in order to cope with pest problems. Damage estimates of the sort considered in this section reflect output foregone: goods and services which would have been available to society in the absence of the relevant pest.

Argentine Stem Weevil

Somewhat unexpectedly, the largest economic damage estimate located in research for this paper was for a small and little-known insect pest. Prestidge and co-workers[16] identified Argentine stem weevil as 'New Zealand's most important insect pest'. The weevil infests all 7 million hectares of pasture land in New Zealand and causes reduced carrying capacity, premature pasture renovation, and various animal health problems associated with pasture quality such as ryegrass staggers, facial eczema and bloat. Scientific recognition of the extent of damage caused by the weevil came only with the introduction of resistant strains of ryegrass, which provided a comparator to measure the weevil's effects on established non-resistant grasses. Since 1982 the spread of resistant strains has somewhat reduced the extent of damage. Calculations to estimate systematically the New Zealand-wide impact of the weevil found that total annual costs lay somewhere between $78 million and $251 million per year, measured in terms of foregone livestock output.[17]

Costs were measured in two distinct ways. For pasture loss and forced renovation, the foregone carrying capacity was calculated in terms of equivalent stock units. Each stock unit was valued at $30[18] to obtain an annual cost estimate of between $46 million and $202 million.

For animal health effects, the estimated cost of morbidity/mortality per stock unit was multiplied by the number of total stock units to obtain a cost estimate for each of the three health problems analysed. For ryegrass staggers the cost was estimated as $3 per stock unit, with 50-70% of this attributable to stem weevil. Multiplying by the 14.3 million stock units in Hawkes Bay and Canterbury (the two regions most affected by staggers) gave a cost of $21.4 million to $30 million for those two regions, which was then entered as a lower-bound estimate of the nationwide cost.

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[16] Prestidge et al. 1991.

[17] Ibid pp.166-168.

[18] The valuation of a stock unit presents some difficulties. MAF (1997) p.99 gives the same $30 figure as Prestidge et al. Other recent studies, however, have used a figure of $17 gross margin per stock unit in estimating pest damage costs (e.g. Parkes 1995, p. 25). Use of the lower figure would reduce the Prestidge et al. total damage figure by about $50 million per year. Considering that this is only one-third of the $170 million range in their study between the high and low damage estimates, we have retained their mean figure in the present calculations.

For facial eczema, a total annual cost of $63 million to $126 million had been estimated for sheep about 1990[19]; a cost estimate of $4.1 million in 1991 dollars for cattle in Manawatu and Taranaki was taken from Faull (1986) and grossed up to a nationwide estimate of $16 million annually. Of the resulting nationwide losses of between $79 million and $158 million, about 10% was assumed due to stem weevil, giving a cost estimate of $8 million to $16 million per year.

For bloat, 10% of nationwide damage was again attributed to stem weevil. Bloat costs comprise cow mortality valued at $750 per milking cow (giving a total of $16.7 million per year), plus farmers' expenditures on bloat-reducing chemicals of $16 million per year[20]. The total is $33 million annually of which 10% or $3 million was assumed due to stem weevil.

Table 5 summarises the estimates by Prestidge et al. The dominant cost component was the reduction in carrying capacity due to pasture damage, which contributed 60-80% of the costs.

The costs of weevil infestation in Table 5 are of the same order of magnitude as the total recorded New Zealand-wide farm expenditure on weed and pest control shown in Table 4. This puts the stem weevil damages estimates in clear perspective.

Table 5: Argentine Stem Weevil Damage Estimates

$ million per year

	Low estimate	High estimate	Mean
Reduced carrying capacity	39.3	174.9	107.1
Pasture renovation	6.8	27.2	17.0
Ryegrass staggers	21.4	30.0	25.7
Facial eczema	8.0	16.0	12.0
Bloat	3.3	3.3	3.3
Total	**78.8**	**251.4**	**165.1**

Source: Prestidge et al. 1991.

California Thistle

Another agricultural pest for which at least partial cost estimates are available is Californian thistle. Mitchell and Abernethy[21] state that Californian thistle is 'the most economically important weed of intensively grazed pasture land in southern Otago and Southland'. They report a 1989 survey of 120 farms which found 33% of the grazing area was infested with thistle. 'It was estimated that the cost of control and loss of production caused by the weed was $3,500 per farm per annum which equates to a regional cost of $21,000,000. Similar results were obtained from a later survey of farmer opinion in the Gore area.... In this survey an average of 9.6 hectares per farm was affected and the cost of control measures and loss of grazing was estimated at $3,100 per farm per year'. Mitchell and Abernethy went on to describe experimental control techniques, but provided no cost information nor cost-benefit analyses of these.

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[19] NZ Meat and Wool Board 1990.

[20] We assume that including this component of the Prestidge et al cost estimates here does not involve double-counting with the 'weed and pest control' expenditures by agriculture already identified earlier. Bloat control would form part of the 'animal health and breeding' row in Table 4, which was not included in the expenditure estimates.

[21] Mitchell and Abernethy 1993, p. 278

From the point of view of the cost estimates being assembled here, the Mitchell and Abernethy data clearly cannot simply be included without some double counting, since they incorporate both loss of production and costs of control. In the absence of information on the weighting of these two components, we simply take half of their total cost estimate as lost production, giving an estimate of about $10 million per year for Otago-Southland. Ideally this should then be marked up to give a New Zealand-wide estimate of thistle costs, but the appropriate multiplier would depend heavily on the incidence of thistle in other regions and the extent to which its presence impedes agricultural production. It is probably safe to assume that the resulting figure would lie above $10 million, possibly as high as $20 million.

Rabbits

Rabbits are another pest with a direct impact on agricultural production, since rabbits compete with farm livestock for available feed. Expenditures on rabbit control have been at a high level for the past half century. The willingness to undertake this expenditure (especially since in the era of Rabbit Boards much of the funding came from local rates) clearly reflected the perception of farmers that, if not controlled, rabbits posed a serious threat to agricultural productivity.

The Ministry of Agriculture and Fisheries[22] has estimated that 56% of the New Zealand land area is occupied by rabbits, but only 9% of the land is moderately to highly rabbit-prone. The report notes that 'the lack of quantified information about the damage rabbits cause to the New Zealand environment makes it difficult to assess the impact of the rabbit as a pest'[23], and comments that (p.3) 'for properties with land of moderate to extreme rabbit proneness the cost of rabbit control is often greater than the financial returns that control brings'[24]. The implication is that rabbit control expenditures have been carried to the point where marginal benefit and (private) marginal cost have been roughly equated.[25]

This reflects the fact that the most rabbit-prone land tends also to be inherently low-productivity land for agricultural use. 'The majority of New Zealand sheep and cattle farmers do not have an economic problem with rabbits....[R]elatively few people and a small area are adversely affected by rabbits'[26]. Nevertheless, the report estimated that 'the loss of grazing due to rabbits is estimated to be sufficient to support between 2 and 4.6 million sheep nation-wide'[27]. Using the same valuation of $30 per stock unit as Prestidge et al.[28], this would imply foregone output of between $60 million and $138 million. Valuing a stock unit at $17 would reduce this to the range $34-78 million.

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[22] 1997, pp. 3 and 8.
[23] Ibid. p. 8.
[24] Ibid. p. 3.
[25] For explicit discussion of this point see Gibb 1967 and Parkes 1995.

Other available estimates of rabbit damage vary extremely widely and more research is needed to clarify the issue. At the low end, Parkes[29] gives an estimate of rabbit damage to pastoral production, horticulture and forestry totalling only $6.8 million per year for a rabbit population of 18 million. This is based on a stated coefficient of 42.2 grammes wool loss per sheep per rabbit, but Parkes' calculation as presented seems to have neglected to multiply by sheep numbers in the relevant regions, and hence may well be too low. Other Australian experimental evidence reported by Parkes[30] indicated an economic loss of A$62 per hectare on improved pasture with 639 mm annual rainfall — conditions not dissimilar to much of Central Otago — which would be indicative of total rabbit-induced costs in excess of $100 million per year if, say, 2 million hectares is taken as an estimate of the New Zealand-wide equivalent area affected.

Estimates also vary of the number of rabbits displacing one sheep by pre-empting pasture feed. Wodzicki[31] suggested fifteen rabbits as equivalent to one sheep; other studies have used lower numbers. At a sheep-displacement ratio of 15, a rabbit population of 20 million would displace 1.3 million sheep - considerably fewer than the Ministry of Agriculture and Fisheries estimate cited above (which may have been based on a lower displacement ratio or a higher estimate of rabbit numbers). Sheep displacement on this scale would imply costs of $40 million annually at $30 per stock unit, or $23 million at $17 per stock unit.

We were not able to locate any authoritative estimate of the total rabbit population. For the purpose of estimating a damage figure for the present paper, it has been assumed that 2 million sheep are displaced by rabbits, and that a sheep is valued at $25. This gives a total cost figure of $50 million per year, with a possible range from perhaps $10 million to over $100 million.

Possums

Possums have a very substantial impact on forest canopies in the conservation estate, cause damage to fruit and other crops, and are the main vector for spread of bovine tuberculosis. Their direct impact on output, however, is not well quantified, and is probably held to a relatively low level by the substantial control expenditures, estimated by Cowan[32] as $30-40 million per year. The potential costs of increased TB rates, with

[26] Ministry of Agriculture and Fisheries 1997, p.9.

[27] Ministry of Agriculture and Fisheries 1997, p. 10.

[28] Ministry of Agriculture and Fisheries 1997, p. 99 Appendix 1 footnote 18 gives the same figure of $30 gross margin per stock unit.

[29] Parkes 1995, p. 26.

[30] Parkes 1995, p.24, reporting work by Crofts.

[31] Wodzicki n.d., p.2.

[32] Cowan 1993, p. 283.

the attendant risks to overseas market access, are very large indeed (dairy product exports are worth over $3 billion per year). These are, however, prospective costs, not actual ones. It seems probable that the main effect of possum eradication would be benefits to indigenous forests and wildlife, rather than to human 'productive' economic activity. Livingstone[33] notes that 'in 1991/92 the direct loss to farmers from the reduction in the value of TB-reactor cattle, deer, and their carcases was estimated at $2.0 million'. This figure lies far below the annual expenditure on control and research spending, which Livingstone estimated as $33 million annually, very close to Cowan's $30 - 40 million.[34]

Detailed figures assembled by the Parliamentary Commissioner for the Environment[35] showing Government, farmer and ratepayer funding for possum and TB control and research show a total of $34 million in 1992/93 and 58 million in 1993/94. The latter figure comprised $30.6 million of spending on possum control; $17.1 million on TB testing, compensation, and Animal Health Board administrative and publicity costs; and $10.3 million of research spending. The possum population was estimated as 60 - 70 million[36], and eradication was judged to be 'not a realistic option with present resources and technology', although it was 'still a viable research objective'[37].

An unsourced article in the 1994 edition of the *New Zealand Official Yearbook*[38] estimated the cost of possums to the New Zealand economy as $44 million per year. Itemised costs given (which actually sum to $53 million rather than the stated $44 million) were:

- expenditure in 1990 of $13 million to control bovine tuberculosis plus $2 million to protect power poles and electrical equipment;
- spending on research to control or manage the possum problem of $7 million in 1991/92;
- additional funding made available in 1993 to the Department of Conservation ($3 million) and the Animal Health Board ($6 million) for possum control, and the Ministry of Agriculture ($2 million) for research, giving a total of $11 million additional Government spending;
- consumption of $12 million worth of pasture annually, plus damage of $7 million to $8 million caused to pine plantations, damage to horticulture of $1 million, and between $30,000 and $800,000 damage to poplars and willows planted to limit soil erosion.

Of these costs only $21 million (the last bullet point) was foregone output in agriculture, forestry, horticulture and soil erosion control in the early 1990s.

However, Cowan recently estimated that 'loss of agricultural and forestry production, and damage to erosion-control plantings ... amount yearly to $30 - 60 million'.[39] For the purposes of this study we take a figure of $40 million as our di-

[33] Livingstone 1993, p. 275.

[34] Coleman 1993, p.343 has a lower figure of $8.3 million plus, based on estimates collated from various sources. However his data do not include regional council spending except for disease control, do not include scientific research, and appear to relate to the second half of the 1980s when expenditures were lower than in the 1990s.

[35] Parliamentary Commissioner for the Environment 1994, p. 8, Table 2.2.

[36] Parliamentary Commissioner for the Environment 1994, p. 4.

[37] Parliamentary Commissioner for the Environment 1994, p. 9.

[38] New Zealand Official Yearbook *97th edition, 1994, p.347.*

[39] Cowan 1996, p. 655.

rect damage estimate for possums. Relative to some other pests considered here, therefore, possums cause only moderate direct costs to marketed production, despite being characterised as 'top of the pest list all over the country'[40] and accounting for a major component of the defensive expenditures covered in the present paper.

Clover root weevil

A recently-introduced insect pest, the clover root weevil, has 'the potential to be a bigger problem than rabbits nationally'[41]. This weevil became established in 1996 in the northern half of the North Island. Loss of output for affected dairy farms was estimated at between $360 and $560 per hectare 'giving a total bill for the 7,000 dairy farms in the area where the weevil is established of $200 to $300 million.'[42] These figures appear to be very early estimates (prepared partly to secure research funding), and do not clearly correspond to actual measured output losses. The loss estimate is correspondingly 'soft' and will here be discounted heavily; if the clover root weevil lives up to early fears and spreads further south the economic output losses could nevertheless be very substantial. We have entered this pest as a $20 million direct foregone output cost.

Rose grain aphid

The loss of grain crop production due to rose grain aphid has been estimated at between $1 million and $20 million per year[43]. The level of cost varies with the extent of yield losses due to infestation; the high estimates of these losses ranged from 10% for wheat to 30% for oats. Effective chemical control would cost between $3.6 million and $5 million per year, which would probably fall on private farmers rather than Government.

Powdery mildew

Powdery mildew in peas was estimated to reduce crop yields by $7.4 million per year in the early 1990s.[44] Control costs were estimated as $385,000 per year

Gorse and blackberry

Two major plant pests which have visually obvious effects on available grazing are gorse and blackberry. Gorse in particular encroaches onto marginal grazing land throughout New Zealand and thereby undoubtedly reduces total carrying capacity. We were not able to locate quantitative estimates of the resulting direct cost to agricultural production. However, much of the direct cost of gorse is captured by private expenditures on weed control, which were covered in the previous section on defensive expenditures.

It must be noted that in many areas, gorse colonisation of marginal lands is probably economically optimal, given the prior existence of gorse in New Zealand. Subsidising the clearing of marginal lands, and keeping them in pastoral production, was abandoned as economically inefficient in the mid 1980s, and private decisions of farmers since then will have concentrated control expenditures on those lands for which direct economic benefits exceed control costs. Marginal land colonised by gorse in the short run does not remain infested indefinitely, since gorse acts as a nursery crop for indigenous forest species, and eventual regeneration of indigenous forest cover is therefore a common long-term consequence of gorse infestation. Casual observation of the reversion of extensive areas in the Wellington and Marlborough Sounds areas suggests that the negative effects of gorse on recreational activities such as tramping apply only to a single human generation, and that a large proportion of these costs has already been borne as these areas revert to indigenous vegetation. In the absence of any good information we have entered a figure of $10 million per year as a pure guess of direct costs of foregone output.

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[40] Marshall 1993, p. 321.

[41] S. Goldson of AgResearch, quoted in *New Zealand Herald* 13 February 1998.

[42] G. Christian, 'Hands Off at the Top on Weevil Research', *New Zealand Herald* 13 February 1998.

[43] Grundy 1990.

[44] Falloon et al. 1993, pp. 84 and 86. The estimate was made by grossing-up results obtained from field experiments, assuming a pea-crop area of 13,500 hectares nationwide.

Wasps

Wasps are another pest with direct impacts on agricultural production (mainly due to their impact on bee populations and hence honey production). They also impose direct costs in terms of medical treatment for stings suffered by humans. It has been estimated from a survey of 50 general practitioners and four hospital accident and emergency wards in 1991/92[45] that the costs of wasps in the Auckland area was $33,000-$36,000, excluding hospitalisation costs. The implied nationwide cost of wasp stings is thus unlikely to exceed $100,000 per year. We did not locate any quantification of the monetary impact on honey production. However, the total value of annual output from the beekeeping industry is in the vicinity of $50 million[46]; if wasps are assumed to cause a 2% reduction in the bee population this would imply output losses of perhaps $1 million per year. It is unknown how much wasp nuisance affects tourism revenue during 'bad' wasp years.

Cost summary

Summarising the quantitative data covered in this section, we have the following mean estimates for direct productive losses:

	$ million
Argentine stem weevil	165
Rabbits	50
Possums	40
Californian thistle	20
Clover root weevil	20
Gorse and blackberry	10
Rose grain aphid	9
Powdery mildew	7
Wasps	1
Other (10% guessed)	36
Total of these numbers	**358**

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[45] Dymock and Forgie 1992.

[46] *New Zealand Official Yearbook 1995*, p. 427 gives a figure of $48.2 million.

The category 'other' includes nassella tussock, a plant pest on which large amounts of defensive expenditure have been incurred over long period, but for which there do not appear to be good estimates of actual damage to production; and a wide range of minor pests not separately identified in the research for this paper[47].

Thus we provisionally obtain a figure of $358 million per year for foregone agricultural production due to pests.The list of pests identified above is far from comprehensive, and the 10% contingency estimate is likely to prove on the low side. In particular animal health has been only partially covered (as part of the Prestidge estimate), and microbiological pests of crops and pasture such as fungi and bacteria other than powdery mildew have not been estimated at all.A total figure of as much as $400 million per year for direct production losses could, therefore, almost certainly be sustained with more information.The state of research on this issue is so rudimentary that the best we can achieve in this paper is a very broad order of magnitude that could reasonably be used in assessing the foregone output due to pests.We conclude provisionally that a figure of $400 million is defensible.

This sum is of the same order of magnitude as total public and private defensive pest control expenditure - nearly half a percent of GDP - and leads us to suggest that the total direct cost of pests to the New Zealand economy, estimated by adding defensive expenditures and foregone outputs, is at least $840 million per year, around 0.9% of GDP. This figure does not include the more intangible areas of cost discussed in the next section, which are by their nature difficult to measure, and on which there are virtually no satisfactory economic research results available.

5. Damage to the Conservation Estate, and Option Values of Pest Exclusion

In this final stage of analysis comes the most difficult category of costs associated with pests: the intangible costs of damage to the indigenous ecosystems of New Zealand, and the option values of averting new pest introductions. Under this heading come:

- damage by deer and possums to indigenous forests;
- the threat to survival of various native vertebrates (birds, bats, lizards, frogs, etc.) and invertebrates (insects, snails, etc.) from feral cats, stoats, rats and other predators;
- the severe reduction of indigenous freshwater species with the introduction of predatory salmonoids such as trout and large herbivores such as koi carp;
- the threat to indigenous habitats by weeds such as Himalayan honeysuckle and old man's beard and invasive seaweeds such as *Undaria*.

To the extent that averting expenditures are undertaken to limit or reverse this damage, this category of costs have already been counted in the first set of data above. However, there are ongoing welfare losses to New Zealand from the damage to indigenous flora and fauna caused by the presently-tolerated levels of infestation. What price can we put on the continued existence of a species such as kaka? New Zealand's unique indigenous flora and fauna are invaluable taonga to both Maori and Europeans alike.

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[47] These include, for example, tussock moth, *Dothistroma pini*, Dutch elm disease, grass carp, wild horses, broom, old man's beard, wild ginger, Himalayan honeysuckle, heather, waterweeds, magpies and rooks.

Damage to the conservation estate caused by introduced species is clearly substantial. But in estimating the total costs of pests to the New Zealand economy, it is important to distinguish between revealed willingness to pay for control activities on one hand, and damage for which individuals and society as a whole have chosen not to undertake remedial action on the other. The defensive expenditure figures, listed earlier in deriving our $840 million sum, already include large amounts of public sector expenditure on indigenous species and island-habitat restoration, control of possums, goats and deer on conservation lands, control of old man's beard, and indigenous forestry research. Willingness to pay for such measures is indicative of the perceived benefits (measured, one could suppose, in terms of the discounted present benefits of the avoided future damage and potential damage). By contrast, the additional level of costs to be discussed here comprises that damage to the indigenous ecosystem for the repair or avoidance of which society is at present not willing to pay.

The total population of feral goats has been estimated at 300,000[48], compared with 250,000 deer, 14,000 thar, and 'several hundred thousand' wild pigs. In the 1980s the NZ Forest service, and then the Department of Conservation, spent about $1.7 million annually on goat control. This budget was increased to $3.8 million in 1990/91 for what developed into the National Feral Goat Control Plan, with the aim of eliminating around half the feral goat population on the conservation estate[49]. There is a clear distinction between pest eradication programmes which impose time-limited budget requirements, and baseline pest control programmes which require funding on an ongoing basis. Goat control is an example of the latter.

Assuming that feral goat numbers have been brought down since the early 1990s, the conservation estate is still supporting over half a million large mammals (excluding possums, rats, stoats, feral cats) with resulting continuing damage to indigenous flora and fauna. The costs and benefits derived by the human population from these feral mammal populations are difficult to measure because of the inherent difficulty of placing any monetary value on (e.g.) the quality of the forest canopy, and because different costs and benefits are perceived by opposing factions within the population. Deer and thar are a major resource from the point of view of hunters[50], who place a high value on retention of these species as part of the modified ecosystem, and lobby Government accordingly. Damage to indigenous flora is thus to be set against benefits for

[48] Parkes 1993.

[49] Parkes 1993, pp. 71 and 80.

[50] Nugent and Fraser 1993.

hunters and, to some extent, positive benefits for tourism from the existence of species such as thar.

Indicative of the difficulty of striking a balance in evaluating the impacts of introduced large mammals is the intense public debate over the removal of wild horses from the Kaimanawa ranges in 1996/97. An important feature of this debate was the revelation that introduced large-mammal populations possess 'existence value' for many New Zealanders, which may well, for this group, be equal to the existence value of indigenous plant species such as those threatened by the horses.

Smaller mammalian pests pose less of an analytical problem. Possums clearly have low existence value for New Zealanders and impose heavy damage on indigenous forests over and above the cost of defensive expenditures at the present level. Feral cats and stoats which threaten indigenous bird and other species equally have few defenders, as do plant pests such as old man's beard. For these species it would in principle be possible to obtain some measures of economic impact using the contingent valuation methodology[51] but there is little such research undertaken to date.

Besides the direct damage caused by pests already established in New Zealand, account must also be taken of the option value to New Zealand of the absence of some pests. For example, the threat to New Zealand's huge investment in radiata pine plantations from certain species of insects is considerable. Apart from the expenditure on border controls, quarantine, and forestry inspections identified in the first set of data, there is a large implicit insurance premium – corresponding to New Zealand's general policy of self-insuring on these risks.[52]

A form of insurance premium is, as just noted, already paid as border control and quarantine services whose costs were factored in earlier (section 3 above); because of imperfect information about future threats this implicit premium may have been been set too low. Periodically, very large potential damage estimates are circulated in relation to insect pests and diseases which have not yet succeeded in being introduced. Examples are fruit fly, the Asian tiger mosquito which acts as a carrier for dengue fever, and the southern saltmarsh mosquito which can carry Ross River fever. A recent Health Ministry estimate that a dengue fever outbreak would have an economic cost of $250 million has been widely cited in press reports[53]. Similarly substantial estimates circulate of the potential damage to plantation forestry from moth pests such as the gypsy moth.

Animal diseases such as foot-and-mouth and scrapie also present obvious risks of severe economic damage; in these cases, the existing level of preventive expenditure has to date been sufficient to contain at least two scrapie incidents (one in the 1950s and one in the 1980s) and suspected foot-and-mouth outbreaks.

[51] Meister and Wilson-Salt 1993.

[52] This is in contrast to earthquake insurance, for which New Zealand insurance companies hold overseas reinsurance cover.

[53] *The Dominion*: Thursday 17 April 1997 editorial; 15 January 1998 report 'Alert After Deadly Mosquitoes Found in New Zealand'; 19 January 1998 report 'Bugs Wait for No Man'.

The question of whether existing levels of defensive expenditure correspond to the actuarially-appropriate insurance premium against extreme possible events is not susceptible of any conclusive answer (only hindsight can give that). The difficulty is that of imperfect information about the future. Experience to date would suggest that whenever new information becomes available from the scientific community, it is quite rapidly factored into public debate and generally into dedicated increases in government funding for defensive measures. New Zealand is thus more secure than many other countries because its isolated position is combined with a fair level of public awareness and government vigilance.

A provisional conclusion drawn from the absence to date of catastrophic outbreaks of major diseases suggests that defensive expenditures at their current level have sufficed to purchase reasonable security on this front. However, the possibility that diseases of poultry and of ratites (birds like emu and ostrich which are closely related to kiwi) might enter the country has recently raised serious concerns about changes in the way such threats are assessed. Insect pests are another cause of a concern, given the very large damage estimates associated with pasture weevils, human virus-carrying mosquitoes, the periodic discoveries of forest pests such as gypsy moth in the vicinity of major ports, and the arrival of the scolytus beetle which causes Dutch elm disease. Direct financial costs of strengthening existing defences at ports would be of the order of millions of dollars annually rather than hundreds of millions, and there are indications that existing expenditure levels are now too low.

To place any numbers on the existence value of a native taonga species is extremely difficult given the existing state of knowledge. We settle here for a general proposition that a contingent valuation of threatened native species and of the option value of maintaining defences against new potential pests would raise the estimates derived earlier, but by an incalculable amount.

6. Conclusion

Identifiable costs amount to $840 million a year, or 0.9% of GDP. Given that it has not been possible to estimate some costs, the true figure is likely to be close to 1% of GDP. This excludes intrinsic costs, and non-GDP material costs, for which it was not practicable to estimate. In any case, despite their potential importance, it would not be strictly appropriate to compare a total including such non-market costs with a market-based benchmark such as GDP.

New Zealand's GDP in 1996/97 was $96 billion. In present-value terms at discount rates between 5% and 10%, an ongoing annual economic loss of 1% of GDP – that is, $960 million a year – is equivalent to between $9 billion and $19 billion capitalised burden. This, in theory, would represent the value to New Zealand of a guaranteed permanent eradication programme which left no ongoing need for further control or prevention expenditure.

Table 6:
Summary of Study Results

	Estimate $ million		Range $ million	% of GDP
Defensive expenditures:				
Central Government:				
Border control and quarantine	*30*		0.03	
Pest surveillance & response	*25*		0.03	
TB vector control	*20*		0.02	
Pest control on conservation estate	*36*		0.04	
Protected species & island habitats	*32*		0.03	
Other biosecurity activities	*7*		0.01	
Policy advice	*5*		0.01	
Research	*40*		0.04	
Total		195		0.20
Regional Councils net		25		0.03
Intermediate purchases by agricultural sector		180		0.19
10% allowance for other sectors		40		0.04
Total defensive expenditures		**440**		**0.46**
Production Losses:				
Argentine stem weevil		165	78 - 251	0.17
Rabbits		50	10 - 130	0.05
Possums		40	20 - 60	0.04
Thistle		20	10 - 30	0.02
Clover root weevil		20	0 - 300	0.02
Gorse and blackberry		10	10	0.01
Rose grain aphid		9	1 - 20	0.01
Powdery mildew		7	7	0.01
Wasps		1	0.1 - 2	0.00
Allowance for other insect & animal pests		36		0.04
Total to here		358		0.37
Guess for microbiological pests and others		42		0.04
Total production losses		**400**	**178 - 852**	**0.42**
Total quantified costs		**840**		0.88
Gross Domestic Product 1996/97		**96,000**		

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